Detected New Pulsating Component in Eclipsing Binary System GSC 02907-00975

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(Submitted on 21.05.2026; Accepted on 18.07.2026)

Abstract. We present a photometric analysis of the EA-type eclipsing binary TIC 261140858 based on space-based time-series observations from the TESS mission. According to the VSX database, this object was previously classified solely as an EA-type eclipsing binary. Our analysis reveals the presence of a pulsating component within the system, allowing us to identify it as a new oscillating eclipsing Algol (oEA) system. The pulsation period was determined using the Lafler–Kinman method, yielding a value of $P_{\rm pul} = 1.34$ days, corresponding to a pulsation frequency of $f \approx 0.742$ day^{-1}. Additionally, a frequency analysis of the out-of-eclipse light curve was performed using the Period04 software (Lenz & Breger 2005), which confirmed the dominant pulsation signal and enabled a harmonic decomposition of the light curve. The detected pulsation frequency below 3 days^{-1} suggests that the pulsating component is likely of γ Doradus type. Furthermore, the object follows the characteristic $P_{\rm pul}$ and $P_{\rm orb}$ relation observed in oEA systems. We report the first detection of pulsations in TIC 261140858 and provide an updated table of parameters for this system. This object represents a promising target for further studies of binary system evolution and the effects of tidal interactions on stellar pulsations, although many of its physical properties remain to be fully constrained.
Key words: eclipsing binary, pulsating, γ Doradus, oEA, TESS, Period04

Introduction

Binary star systems represent one of the most reliable tools for accurately determining fundamental stellar parameters, including mass, radius, and luminosity, through combined photometric and spectroscopic observations. These parameters are essential for constraining and validating stellar evolutionary models (Andersen 1991). Although the internal structure of stars cannot be observed directly, it can be inferred for pulsating stars using asteroseismology (Aerts et al. 2010). Consequently, binary systems hosting at least one pulsating component have become subjects of considerable interest in stellar astrophysics. In addition to the fundamental parameters derived from binary system analyses, asteroseismology allows for a detailed investigation of the internal structure of the pulsating star. This combined approach provides critical insights into stellar structure and evolution, as well as the influence of tidal interactions on stellar pulsations (Fuller 2017; Fuller et al. 2020; Guo 2021).

Variable stars of the δ Scuti type belong to spectral types ranging from A0 to F5 and are located on the main sequence of the Hertzsprung–Russell diagram, as well as within the classical instability strip. Their masses lie approximately in the range 1.4–2.5 $M_\odot$ (Netzel & Smolec 2022). These stars have attracted considerable attention in recent years due to their large number of radial and non-radial pulsation modes, driven primarily by the κ mechanism operating in the He II ionization zone (Wang et al. 2024). In close binary systems, tidal forces can additionally excite or suppress certain pulsation modes

(Fuller 2017), making oEA systems particularly valuable probes of the interplay between binarity and stellar oscillations.

During the period from 1967 to 1977, several researchers (Tempesti 1971; Broglia & Marin 1974; McInally & Austin 1977) observed the existence of eclipsing binary stars with a pulsating component. To date, the number of such objects that have been observed and are currently being monitored has reached thousands, or even more (Shi et al. 2022). It has been emphasized by Soydugan et al. (2006), Liakos et al. (2012), Zhou (2010), and Liakos & Niarchos (2017) that a large fraction of these objects contain δ Scuti (δ Sct) type pulsating components within classical semi-detached Algol systems. This type of stars was defined as oEA (oscillating eclipsing binaries of Algol type) by Mkrtichian et al. (2002). In recent years, the remarkable success of the *Kepler* and TESS space missions has led to the detection of over 1 000 δ Scuti-type pulsators in eclipsing binaries.

Certainly, EA-type eclipsing binary systems can be either semi-detached or detached. Moreover, in some EA-type systems, the pulsating component is not necessarily the primary star, nor is the system necessarily in a semi-detached configuration, which distinguishes them from the original definition of oEA systems (Shi et al. 2022). Typically, as a result of mass transfer from the secondary to the primary component (Guo et al. 2017; Miszuda et al. 2021), the primary component of oEA stars is located in the lower part of the classical Cepheid instability strip and exhibits δ Scuti-type pulsations. These pulsations have frequencies in the range of 3–80 d^{-1}. Therefore, the pulsation of the primary component should be closely related to the presence of a companion star (Shi et al. 2022). Studies by Mkrtichian et al. (2018, 2022) have further advanced our understanding of the physical processes associated with mass transfer in oEA systems. In particular, magnetic activity cycles have been linked to variations in mass transfer and accretion, which in turn modulate the pulsation amplitudes across all modes (Mkrtichian et al. 2018).

Taking into account the observational properties of pulsating stars in eclipsing binary systems, high-precision and continuous time-series photometric data obtained by space-based telescopes offer unparalleled advantages for the identification and investigation of oEA stars. These observational features include, in particular, the manifestation of small-amplitude pulsations of the pulsating components in the light curves of binary systems, as well as orbital periods that are typically close to or longer than one day (Shi et al. 2022). In this study, based on TESS observations, we report the identification of one of the stellar components in an EA-type eclipsing binary system as a pulsating star, and we present a preliminary analysis of the pulsational properties of this object.

1. Data Source

1.1. Catalog information

As mentioned above, EA-type eclipsing binary star systems are currently listed in numerous catalogs. In particular, according to the VSX (International Variable Star Index) (Watson et al. 2006) catalog, a total of more than 120 000 EA-type eclipsing binary systems had been registered as of January 2025.

These objects have also been observed and are being observed by the TESS space telescope. Among them, a significant subset is expected to harbor pulsating components, as demonstrated by large-scale surveys (Shi et al. 2022).

1.2. TESS observations

In April 2018, NASA launched the Transiting Exoplanet Survey Satellite (TESS; Ricker et al. 2015) as a space mission designed to search for exoplanets. TESS observes bright stars in a 2-minute short-cadence mode and provides full-frame images every 30 minutes. The primary goal of the TESS mission is to detect transiting planets around bright and nearby stars across the entire sky. In addition, its high-precision photometric data offer unprecedented opportunities for the study of binary systems and variable stars (Shi et al. 2022). NASA's TESS mission has conducted a groundbreaking near all-sky space-based survey for small transiting exoplanets around bright stars. At the core of the TESS spacecraft are four cameras, each equipped with a 2K $\times$ 2K CCD detector, collectively providing a total field of view of $24^\circ \times 96^\circ$, using wide-field cameras with 105 mm aperture and a focal ratio of $f/1.4$. Owing to this extensive field coverage, the resulting angular resolution is relatively coarse, at approximately $21''$ per pixel. TESS surveys the sky by dividing it into sectors and observing with a wide TESS passband filter spanning 600–1000 nm, enabling photometric measurements with a precision of about 50 ppm for stellar targets. Each sector has around 27 days of photometric observations (Ricker et al. 2015).

The object GSC 02907-00975 was observed by TESS in Sectors 19, 59, 73, and 86 during 2019, 2022, 2023, and 2024, respectively. Its TESS light curve is shown in Fig. 1. The basic parameters of the system as listed in the VSX catalog are presented in Table 1.

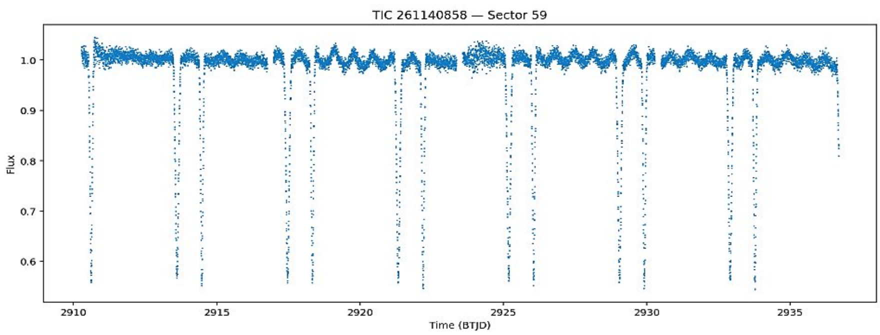

Fig. 1. The overall light curve of TIC 261140858 observed by TESS in Sector 59.

The object TIC 261140858 has an eccentric orbit, as the two eclipse phases are not separated by exactly 0.5 in phase (Shi et al. 2022). Eccentric orbits are particularly important in the study of tidal interactions, since a non-circular orbit implies time-varying tidal forces on the stellar components, which can drive or suppress oscillation modes through resonance locking mechanisms (Fuller 2017).

Table 1. Basic parameters of TIC 261140858 / GSC 02907-00975 from the VSX catalog.

TESS ID	Name	Coords(J2000)	Period (d)	Mag. range(V)	Type
261140858	GSC 02907-00975	05:05:13.5 +43:31:50.4	3.860	13.39–14.02	EA

All the data presented in Table 1 were taken from the International Variable Star Index (VSX) catalog.

2. Methods

2.1. Light curve preparation

The TESS light curves used in this study were obtained from the Mikulski Archive for Space Telescopes (MAST). We employed the Pre-search Data Conditioning Simple Aperture Photometry (PDCSAP) flux, which is corrected for systematics and instrumental artifacts. Data points with quality flags indicating anomalous behavior were removed prior to analysis. The resulting light curves were normalized by dividing each flux measurement by the out-of-eclipse median flux.

2.2. Eclipse removal

To determine the main pulsation frequency, the data points corresponding to the eclipse phases were removed from the light curve (Fig. 2). The eclipse boundaries were identified by folding the full light curve on the known orbital period of 3.86034 days and visually determining the ingress and egress phases. Both the primary and secondary eclipses were masked out before the pulsation analysis was performed. This approach follows the standard procedure described by Shi et al. (2022) for the extraction of intrinsic pulsation signals from binary light curves.

2.3. Period analysis: the Lafler–Kinman method

The pulsation period of the system was determined using the Period Search Service software, which implements the Lafler & Kinman (1965) method. This technique is well suited for unevenly sampled photometric time-series data and is based on minimizing the scatter of the phase-folded light curve. For each trial period, the observations are folded in phase and sorted accordingly. The sum of the squared differences between successive magnitude values is then calculated. The true pulsation period corresponds to the minimum of this statistic. The Lafler–Kinman method does not assume any specific light-curve shape and is therefore particularly effective for non-sinusoidal pulsations (Lafler & Kinman 1965). We searched for periods in the range of 1.0 to 1.5 days. The resulting periodogram is shown in Fig. 3.

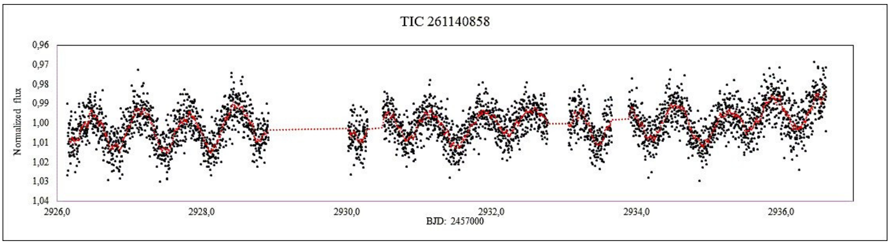

Fig. 2. The light curve of TIC 261140858 after removing the data during eclipses.

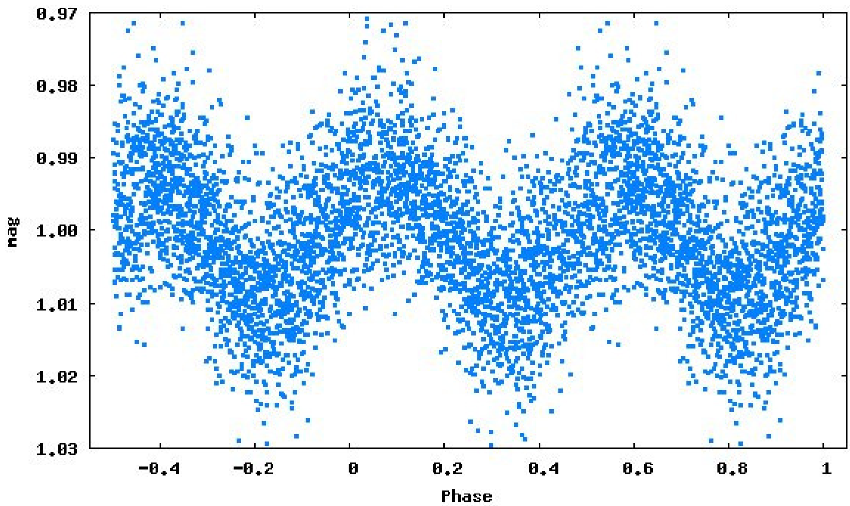

Fig. 3. The light curve identified on Lafler & Kinman periodograms in the specified trial period range (1.0 to 1.5 days).

2.4. Frequency analysis with Period04

To further characterize the pulsational content of TIC 261140858, a frequency analysis of the eclipse-removed light curve was carried out using the Period04 software package (Lenz & Breger 2005). Period04 is a widely used tool in asteroseismology that performs Fourier analysis and multi-frequency least-squares fitting of time-series data. The software computes amplitude spectra and iteratively pre-whitens the dominant frequencies to search for lower-amplitude signals. This approach has been applied extensively in studies of δ Scuti and γ Doradus stars observed by space photometry missions such as *Kepler* and TESS (Juraev et al. 2025; Lenz & Breger 2005).

For each detected frequency f_i, the amplitude A_i, phase ϕ_i, and signal-to-noise ratio (SNR) were determined. Following standard practice, a frequency was considered significant if its SNR exceeded 4.0 (Breger et al. 1993). The mathematical model of the brightness variation was then constructed as a sum of sinusoidal components:

$$y(t) = b + \sum_i A_i \sin(2\pi f_i t + \phi_i), \tag{1}$$

where b is a constant offset, and t is the observation time in Barycentric Julian Date (BJD). The dominant frequency obtained from Period04 was found to be consistent with the pulsation period derived independently by the Lafler–Kinman method, providing a mutual confirmation of the result.

3. Results and Discussion

3.1. Pulsation properties

The object TIC 261140858 is classified in the VSX database solely as an EA-type eclipsing binary. Our analysis, however, reveals the presence of a pulsating component within this system, identifying it as an oEA star. Using the Lafler–Kinman method, the pulsation period was determined to be $P =$ 1.3477816 days, corresponding to a pulsation frequency of $f \approx 0.742$ day^{-1}. The observed period and the phase-folded light curve are consistent with the typical pulsational behavior of oEA stars in EA-type systems.

The frequency analysis with Period04 yielded a dominant frequency of $f_0 \approx 0.742$ day^{-1} with a high SNR, confirming the Lafler–Kinman result. The amplitude spectrum shows no additional significant peaks above the adopted SNR threshold within the γ Dor frequency range (0.3–3 day^{-1}), indicating that the light variation is dominated by a single pulsation mode. This is qualitatively similar to the findings of Juraev et al. (2025) for the δ Scuti star TIC 372275195, where a single fundamental frequency was identified as the dominant mode despite the availability of multi-sector TESS data.

The detected pulsation frequency of $f \approx 0.742$ day^{-1} falls well below the characteristic δ Scuti threshold of 3 day^{-1}. This places TIC 261140858 in the regime associated with γ Doradus-type pulsators, which typically exhibit gravity-mode (g-mode) oscillations with frequencies in the range of 0.3–3 day^{-1} (Aerts et al. 2010). The γ Dor instability strip overlaps with the δ Sct strip near the main sequence in the Hertzsprung–Russell diagram, and some stars show hybrid behavior combining both types of pulsations (Guo et al. 2017).

3.2. Pulsation constant and physical model

Following the approach applied to similar pulsating stars (Juraev et al. 2025), we estimate the pulsation constant Q for the pulsating component of TIC 261140858 using the relation (Christensen-Dalsgaard 1993; Handler & Shobbrook 2002):

$$P_0 = Q\sqrt{\frac{\rho_\odot}{\bar{\rho}}}\,, \tag{2}$$

where P_0 is the fundamental pulsation period, $\rho_\odot$ is the mean density of the Sun, and $\bar{\rho}$ is the mean density of the pulsating star. Equivalently,

$$Q = P_0 \cdot \left(\frac{R_\odot}{R}\right)^{3/2} \cdot \left(\frac{M}{M_\odot}\right)^{1/2}. \tag{3}$$

Since the absolute physical parameters of TIC 261140858 have not yet been determined from spectroscopy, a precise calculation of Q is not yet possible. Nevertheless, once radial velocity observations are available, this relation will allow a direct assessment of the pulsation mode and internal structure of the oscillating component, following the methodology described by Handler & Shobbrook (2002) and demonstrated for TIC 372275195 by Juraev et al. (2025).

The empirical relation between pulsation period and mean stellar density, $P_0 \propto 1/\sqrt{\bar{\rho}}$ (Christensen-Dalsgaard 1993), implies that more evolved, lower-density stars pulsate with longer periods. Given the γ Dor classification of the pulsating component in TIC 261140858, the detected period of ~ 1.35 days is consistent with the typical density regime of late A- to early F-type main-sequence or slightly evolved stars. The γ Dor instability is driven by a convective flux blocking mechanism at the base of the convective envelope (Guzik et al. 2000), which is active in stars with effective temperatures in the range of approximately 6800–7900 K. Results from several databases and catalogs indicate that the object's mean effective temperature (Teff) is 7214.821 K and its mass is 1.499109 solar masses. (Khalatyan et al 2024).

3.3. Tidal effects and the $P_{\rm pul}$–$P_{\rm orb}$ relation

A key diagnostic for oEA stars is the relationship between the pulsation period $P_{\rm pul}$ and the orbital period $P_{\rm orb}$. This empirical relation has been established for both δ Sct and γ Dor type pulsators in binary systems (Soydugan et al. 2006; Liakos et al. 2012; Hoyman et al. 2020). Tidal forces in close binary systems can significantly modify the pulsational behavior of the component stars. In systems with short orbital periods, tidal locking tends to synchronize stellar rotation with the orbital motion, which in turn affects the excitation and damping of pulsation modes (Fuller 2017; Van Reeth et al. 2023). Resonance locking between orbital harmonics and stellar oscillation modes has been proposed as a mechanism to explain the presence of tidally excited pulsations in eccentric binaries (Fuller et al. 2020).

The identified object TIC 261140858 exhibits a distribution trend consistent with the $P_{\rm pul}$–$P_{\rm orb}$ relation characteristic of oEA stars. The orbital period of $P_{\rm orb} = 3.86034$ days and the pulsation period of $P_{\rm pul} = 1.347$ days place this object in a region of the $P_{\rm pul}$–$P_{\rm orb}$ diagram that is occupied by γ Dor type pulsators in eclipsing binaries, as documented by Hoyman et al. (2020) Furthermore, Van Reeth et al. (2023) demonstrated that γ Dor stars in eclipsing binaries frequently show tidally perturbed g-mode pulsations, especially when the orbital period is shorter than 10 days, which is consistent with the properties of TIC 261140858 (Fig. 4).

Figure 4 shows that the correlation value between $P_{\rm pul}/P_{\rm orb}$ for the newly identified object is 0.3489, as indicated in the overall diagram derived from the results of Zhang et al. (2013), Shi et al. (2022) and Liakos et al. (2012). The $P_{\rm pul}/P_{\rm orb}$ value confirms that the component of the identified obscured binary system is γ Dor.

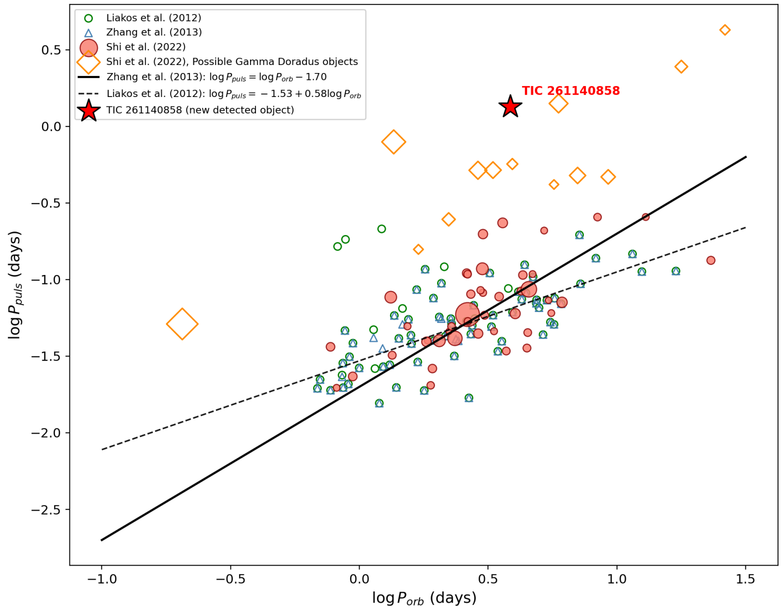

Fig. 4. The position of the new pulsating star in EA-type eclipsing binaries on the pulsation–orbital period relation diagram for oEA stars.

3.4. Classification and updated parameters

We summarize the updated parameters of the system in Table 2. Based on our analysis, TIC 261140858 is reclassified from a simple EA-type eclipsing binary to an oEA system harboring a γ Dor-type pulsating component.

Table 2. Updated parameters of TIC 261140858.

TESS ID	$P_{\rm pul}$ (d)	$P_{\rm orb}$ (d)	Var. type	Puls. comp. type
261140858	1.347	3.86034	oEA	γ Dor

The γ Dor classification is further supported by the typical mass range of such pulsators, which lies between 1.4 and 2.0 $M_{\odot}$ with effective temperatures between about 6800 and 7900 K (Aerts et al. 2010). Stars in this temperature range occupying the appropriate instability strip are driven to pulsate through the convective flux blocking mechanism (Guzik et al. 2000). The eccentric orbit of TIC 261140858, combined with its pulsation characteristics, makes it a particularly interesting candidate for studying resonance locking between orbital and pulsation modes (Fuller et al. 2020; Van Reeth et al. 2023).

Conclusion

According to the International Variable Star Index (VSX), TIC 261140858 is classified only as an EA-type eclipsing binary, and no pulsational behavior has been reported so far. We report the first detection of pulsations in the EA-type eclipsing binary TIC 261140858 and consequently identify this system as a new oEA system. The pulsation period was determined using both the Lafler–Kinman method and the Period04 frequency analysis software (Lenz & Breger 2005), with both approaches yielding a consistent dominant frequency of $f \approx 0.742$ day^{-1} ($P_{\rm pul} = 1.347$ days).

The identified object TIC 261140858 exhibits a distribution trend consistent with the $P_{\rm pul}$–$P_{\rm orb}$ relation characteristic of oEA stars, confirming its classification as an oEA system. At the same time, this object pulsates at a frequency below 3 d^{-1}, which indicates that the pulsating component likely belongs to the γ Doradus (γ Dor) type (Shi et al. 2022; Aerts et al. 2010). The eccentric nature of the orbit further enriches the scientific value of this system, as it opens the possibility of investigating tidally excited and tidally perturbed g-mode oscillations (Fuller 2017; Van Reeth et al. 2023).

Finally, we present an updated table of parameters for the object TIC 261140858 (Table 2). This newly identified object represents a highly interesting target for a deeper investigation of the formation and evolution of binary systems, as well as for studying the effects of tidal forces and mass transfer on stellar pulsations (Shi et al. 2022). Future spectroscopic observations will be essential to determine the absolute stellar parameters (masses, radii, effective temperatures) of both components, which will allow a full asteroseismic characterization of the pulsating star and a precise test of evolutionary models for mass-transferring binary systems (Miszuda et al. 2021).

References

Andersen J., 1991, *Astron. Astrophys. Rev.* 3, 91–126
Aerts C., Christensen-Dalsgaard J., Kurtz D. W., 2010, *Asteroseismology*, Springer, Berlin
Broglia P., Marin F., 1974, *Astron. Astrophys.* 34, 89–97
Breger M., Stich J., Garrido R., et al., 1993, *Astron. Astrophys.* 271, 482–486
Christensen-Dalsgaard J., 1993, in: IAU Colloq. 137: Inside the Stars, W. W. Weiss & A. Baglin (eds.), *ASP Conf. Ser.* 40, 483
Fuller J., 2017, *Mon. Not. R. Astron. Soc.* 472, 1538–1564
Fuller J., Kurtz D. W., Handler G., Rappaport S., 2020, *Mon. Not. R. Astron. Soc.* 498, 5730–5744
Guo Z., 2021, *Front. Astron. Space Sci.* 8, 639003
Guo Z., Gies D. R., Matson R. A., García Hernández A., Han Z., Chen X., 2017, *Astrophys. J.* 837, 114
Guzik J. A., Kaye A. B., Bradley P. A., Cox A. N., Neuforge C., 2000, *Astrophys. J. Lett.* 542, L57–L60
Handler G., Shobbrook R. R., 2002, *Mon. Not. R. Astron. Soc.* 333, 251–262
Hoyman B., Çakırlı Ö., Özdarcan O., 2020, *Mon. Not. R. Astron. Soc.* 491, 5980–5990
Juraev B. Sh., Burkhonov O. A., Ehgamberdiev Sh. A., Karimov R. G., Muminov M. M., 2025, *Perem. Zvezdy* 45, No. 13, 115–123
Khalatyan A, Anders F,Chiappini C, Queiroz ABA, Nepal S, et al. 2024. Transferring spectroscopicstellar labels to 217 million Gaia DR3 XP stars with SHBoost. Astron. and Astrophy. 691: A98
Lafler J., Kinman T. D., 1965, *Astrophys. J. Suppl. Ser.* 11, 216
Lenz P., Breger M., 2005, *Commun. Asteroseismol.* 146, 53–136

Liakos A., Niarchos P., 2017, *Mon. Not. R. Astron. Soc.* 465, 1181–1200
Liakos A., Niarchos P., Soydugan E., Zasche P., 2012, *Mon. Not. R. Astron. Soc.* 422, 1250–1262
McInally C. J., Austin R. D., 1977, *Inf. Bull. Var. Stars* 1334, 1
Miszuda A., Szewczuk W., Daszyńska-Daszkiewicz J., 2021, *Mon. Not. R. Astron. Soc.* 505, 3206–3218
Mkrtichian D. E., Kusakin A. V., Gamarova A. Y., Nazarenko V., 2002, in *IAU Colloq. 185: Radial and Nonradial Pulsations as Probes of Stellar Physics*, *ASP Conf. Ser.* 259, p. 96
Mkrtichian D. E., Lehmann H., Mader J. A., et al., 2018, *Mon. Not. R. Astron. Soc.* 475, 4745–4767
Mkrtichian D. E., Gunsriviwat K., Lehmann H., et al., 2022, *Galaxies* 10, 97
Netzel H., Smolec R., 2022, *Mon. Not. R. Astron. Soc.* 515, 4574–4589
Ricker G. R., Winn J. N., Vanderspek R., Latham D. W., Bakos G.Á., et al., 2015, *J. Astron. Telesc. Instrum. Syst.* 1, 014003
Shi X.-d., Qian S.-b., Li L.-J., 2022, *Astrophys. J. Suppl. Ser.* 259, 50
Soydugan E., İbanoğlu C., Soydugan F., Akan M. C., Demircan O., 2006, *Mon. Not. R. Astron. Soc.* 366, 1289–1294
Tempesti P., 1971, *Inf. Bull. Var. Stars* 596, 1
Van Reeth T., Johnston C., Southworth J., et al., 2023, *Astron. Astrophys.* 671, A121
Wang J., Chen X., Deng L., et al., 2024, *Astrophys. J.* 978, 53
Watson C. L., Henden A. A., Price A., 2006, *Soc. Astron. Sci. Annu. Symp.* 25, 47
Zhang X. B., Luo C. Q., Fu J. N., 2013, *Astrophys. J.* 777, 77
Zhou A.-Y., 2010, arXiv:1002.2729