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DISCOVERIES OF FOUR δ SCUTI STARS

LIAKOS, ALEXIOS

1) Institute for Astronomy, Astrophysics, Space Applications and Remote Sensing, National Observatory of Athens, Metaxa & Vas. Pavlou St., GR-15236, Penteli, Athens, Greece, alliakos@noa.gr

Abstract: Four stars, namely TYC 1615-03493-1, TYC 3672-00435-1, GSC 3672-0481, and TYC 5130-00273-1, are announced as new variables for the first time. The stars were observed as by-product and by applying standard photometry techniques, their light curves were obtained and analyzed using Fourier transformation methods. The results of the analyses showed that all of them are δ Scuti type pulsators, they exhibit multi-periodic oscillations and their dominant pulsation frequencies are derived.

1 Introduction

The pulsating stars of δ Scuti type exhibit short-period radial and non-radial mode oscillations triggered mostly by the κ -mechanism (Aerts et al., 2010). They are mostly located inside the classical instability strip of the HR diagram, they have masses between 1.4 and 2.5 M_{\odot} and temperatures between 6500-9500 K (Aerts et al., 2010; Murphy et al., 2019). The present work announces the discoveries of four δ Scuti stars observed as by-product during observations of other variables and focuses on the determination of their dominant pulsation frequencies.

2 Observations and data reduction

The observations were made at the Kryoneri Observatory¹ (IAU MPC code: L10), located at Mt. Kyllini (alt~930 m), Corinthia, Greece using the 1.2 m telescope (Xilouris et al., 2018). The Apogee CG47 CCD camera (e2V CCD47-10 chip, pixel size 13 μ m and a total of 1024×1024 pixels), which was equipped with V filter from the Bessell UBVRI photometric filter set, was used. The field of view of this setup is 12.3' × 12.3'. The data acquisition was made between November 2021 and July 2022 and the aim of the observations concerned other variable stars. The newly discovered pulsating stars were inside the field of views of the other targets-variables and were observed as by-product. The detailed observation log is given in Tab. 1. The finding charts of the new variables are illustrated in Fig. 1. All the information, gathered from online catalogues and databases, for the new variables as well as for the comparison and check stars used for the photometry is given in Tab. 2. In particular, this table lists the designation (des.) of each star, as shown in Fig. 1, its coordinates, its magnitude in V band and two cross identifications with other catalogs.

¹http://kryoneri.astro.noa.gr

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Star	Observations dates	Total observed hours	Exposure [s]	Data points
TYC 1615-03493-1	21-Jun 2022	4.16	15	808
TYC 3672-00435-1 GSC 3672-0481	30-Nov and 1-Dec 2021	11.72	10	2359
TYC 5130-00273-1	24-Jul 2022	6.20	10	999
RI CI V602 AqL	Е. V2 V3 (<u>сз</u> , к2 к3 (<u>сз</u> , к2 к3	E E (2) FoV 12.3'*12.3'	<u>va</u> <u>ca</u>	YZ Aq1 YZ Aq1 FoV 12.3'×12.3

Table 1: Log of observations.

Figure 1: Finding charts of the new variables. The left chart corresponds to TYC 1615-03493-1 (V1), the middle to TYC 3672-00435-1 (V2) and GSC 3672-0481 (V3), and the right to TYC 5130-00273-1 (V4). The comparison and check stars used for the photometry of each variable are denoted with the C and K letters, respectively. The orientation, the field of view (FoV) of the setup, and the positions of other already known variable stars in each field are also indicated. Details for all stars are given in Tab. 2.

The differential aperture photometry method was applied for the data analysis using the *C-MUNIPACK* software package (*Muniwin* v.1.1.26; Hroch, 1998). Full calibration, i.e. bias and dark images subtraction and flat-field correction, was applied in all scientific images.

3 Analysis and results

The oscillation frequencies analysis was employed the software PERIOD04 v.1.2 (Lenz et al., 2005) that is based on classical Fourier analysis. Although the typical frequencies of δ Sct stars range between 4-80 d⁻¹ (Breger, 2000), an extensive range between 0-80 d⁻¹ was selected for the search. The reason is that many δ Sct stars exhibit hybrid behaviour of γ Dor- δ Sct type (c.f. Murphy et al., 2019) or may present g-mode pulsations (i.e. long-period oscillations, c.f. Sekaran et al., 2020) or low-frequency oscillations in the case of being members of close binary systems (c.f. Liakos, 2017).

The aim of this work is the announcement of the discoveries of these new variables and the presentation of the evidence of their variability type. Therefore, the search was limited to the detection of the first two or three strongest frequencies in order the calculation of the dominant pulsation frequency (i.e. the frequency with the largest amplitude) to be more accurate. Detailed analysis using more photometric data (ground based or space-

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Des.	Star	α_{2000}^1 [hh mm ss]	$\delta^1_{2000} \ [^{\circ} \ ' \ '']$	V [mag]	TIC No	UCAC4 No
V1	TYC 1615-03493-1	19 50 37.03	$+16 \ 24 \ 49.75$	11.71^{1}	209587036	533-111641
C1	$GSC \ 1615-3077$	$19\ 51\ 15.07$	$+16 \ 30 \ 33.78$	11.92^{2}	209750120	533 - 112164
K1	TYC 1615-01953-1	19 50 59.76	$+16 \ 29 \ 08.75$	10.98^{1}	209586507	533 - 111951
V2	TYC 3672-00435-1	$00 \ 55 \ 07.94$	$+54 \ 31 \ 44.74$	11.09^{1}	312678994	723-008504
C2	TYC 3672-00189-1	$00 \ 54 \ 46.49$	$+54 \ 26 \ 27.70$	10.92^{1}	312678823	723-008441
K2	TYC 3672-00359-1	$00 \ 55 \ 09.10$	$+54 \ 28 \ 43.21$	11.69^{2}	312678905	723-008507
V3	GSC 3672-0481	$00 \ 55 \ 12.88$	$+54 \ 30 \ 09.30$	12.10^{1}	445346014	723-008514
C3	TYC 3672-00359-1	$00 \ 55 \ 09.10$	$+54 \ 28 \ 43.21$	11.69^{2}	312678905	723-008507
$\mathbf{K3}$	$GSC \ 3672-0393$	$00 \ 55 \ 13.37$	$+54 \ 27 \ 58.30$	12.62^{3}	445346093	723-008517
V4	TYC 5130-00273-1	$19\ 17\ 18.04$	$-00\ 42\ 23.10$	10.47^{1}	160956888	447-103051
C4	TYC 5130-02095-1	$19\ 17\ 04.82$	-00 44 33.98	10.95^{2}	160957161	447-102896
K4	GSC 5130-0969	$19\ 17\ 01.22$	$-00\ 45\ 32.25$	10.91^{2}	160957284	447 - 102852

Table 2: Characteristics of the variable and comparison stars taken from catalogues.

¹The TESS Input Catalog (TIC) and Candidate Target List (Stassun et al., 2018), ²UCAC4 Catalogue (Zacharias et al., 2012), ³NOMAD Catalog (Zacharias et al., 2005)

Table 3: The dominant pulsation frequencies of the four newly discovered δ Sct stars.

Star	$f_{dom} [c/d]$	A [mmag]	Φ [2 π rad]
TYC 1615-03493-1	24.58(8)	8.7(2)	0.126(4)
TYC 3672-00435-1	17.549(3)	13.97(9)	0.201(1)
$GSC \ 3672-0481$	32.70(3)	2.2(1)	0.189(9)
TYC 5130-00273-1	31.19(8)	5.3(2)	0.236(6)

born, e.g. from the *TESS* mission) is beyond the scope of this study. Fig. 2 and Fig. 3 illustrate the frequency spectra and the Fourier fitting on the observed data, respectively. As can be easily seen from these plots, all stars exhibit multi-periodic oscillation behavior. The dominant pulsation frequencies along with their respective amplitude (A) and phase (Φ) values are given in Table 3.

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Figure 2: Frequency spectra of the four new δ Sct stars. The dominant frequency for each case is denoted with the symbol f_{dom} and is given in Tab. 3. The spectra of TYC 3672-00435-1 and GSC 3672-0481 are more dense because larger data sets were available for the analysis.



Figure 3: Fourier fitting on the observed data of the four new δ Sct stars.

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