JSTR
ASEAN Journal of Scientific and Technological Reports

Research article

Frequency Analysis of High Amplitude δ Scuti Star V593 Lyr by American Association of Variable Stars Observers International Database

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Citation:
Chehlaeh, N.; Promfu, T.; Masae, N. Frequency Analysis Analysis of High Amplitude δ Scuti Star V593 Lyr by American Association of Variable Stars Observers International Database. *ASEAN J. Sci. Tech. Report.* **2023**, 26(1), 32-39. https://doi.org/10.55164/ajstr.v26i1.247847.

Article history:
Received: December 12, 2022
Revised: January 20, 2023
Accepted: January 25, 2023
Available online: March 21, 2023

Abstract: The new results of light variability and frequency analysis of a high amplitude δ Scuti star (HADS) V593 Lyr were reported. δ Scuti-type variable stars are fascinating short-period stars with luminosity classes from III to V and spectral types from A0 to F6. Their location on the Hertzsprung-Russell (H-R) diagram is in the classical cepheid instability strip. The photometric data in the *V* filter and clear filter of V593 Lyr were collected from the American Association of Variable Stars Observers (AAVSO) international database. Discrete Fourier transformation and pre-whitening methods were used in the Period04 package to examine time-series light curve data. During 15 observational nights, we obtained 28 times of new light maxima magnitude variability and significant pulsation frequencies for the star. The study found that the fundamental frequency of V593 Lyr is 9.7894180 ± 0.0000002 d^{-1}, corresponding to the main pulsation period of about 0.1021511 d and detected its second to fifth harmonics with a signal-to-noise ratio (S/N) of more than four. A study of the pulsation frequencies and period change of HADS stars can estimate their pulsation modes and evolution. Moreover, HADS stars are suitable targets for understanding asteroseismology, which is the subject that applies a star's pulsations to investigate its internal structure, and the high amplitude stars provide reference points for calculating cosmic distances in the Universe.

Keywords: V593 Lyr; Hight-amplitude δ Scuti; Frequency Analysis; AAVSO

1. Introduction

δ Scuti variable stars are intermediate-mass pulsators located on the Hertzsprung-Russell (H-R) diagram close to the main sequence (MS) and within the classical instability strip. This location corresponds to luminosity classes from III to V and spectral types from A0 to F6. This type of variable star consists of several stages of stellar evolution, including main sequence stars, pre-main sequence (PMS), and post-main sequence stars [1], and within the effective temperature range of $6300 \leq T_{eff} \leq 8600$ K [2]. Pulsation periods of δ Scuti stars range from about haft an hour to 5 hours. The known δ Scuti variables are either a part of the main sequence or are up to three magnitudes above it [3]. From ground-based observations, most of δ Scuti stars are discovered to oscillate in radial and nonradial modes, and their frequencies are within the limits of 5–50 d^{-1}.

The partial ionization of He II causes the κ mechanism, which forces the stellar oscillations [4]. The high amplitude δ Scuti star (HADS) is a subclass of δ Scuti stars and pulsates with amplitude in the *V*-filter of $\Delta V \geq$ 0.3 magnitudes [5]. According to statistics from the catalog of Rodriguez et al. in 2000, the study found 155 HADS stars out of 636 δ Scuti stars in the study, equal to a quarter of all targets [6]. HADS stars are suitable targets for understanding asteroseismology, which is the subject that applies a star's pulsations to investigate its internal structure. The photometric and spectroscopic studies of the pulsation frequency and mode of HADS stars reveal information about the internal structure of the stars. The convective core and surface convection zones of these stars are shallow. Therefore, chemical elements from the convective core have the potential to pierce the surrounding radiative zones, both increasing the amount of hydrogen available for nuclear fusion and the main-sequence stars' lifetimes. Asteroseismology can provide a measurement of this convective overshooting [7]. From a pulsational point of view, HADS stars are the simplest case of stellar oscillators because most pulsate in radial mode. They are good examples of understanding asteroseismology. The physics of stellar oscillations is given in the accepted book Asteroseismology [8].

The object in our study is V593 Lyr, one of δ Scuti stars in the HADS list of Wils et al. [9]. Table 1 presents the list of δ Scuti stars, coordinates, the magnitude in *B* and *V*, the possibility for observation, and the approximate value of the highest altitude of the stars from the horizon at the Thai National Observatory (TNO, 98.4853°E, 18.5725°N).

Table 1. The noticeable δ Scuti targets in the HADS list of Wils et al. [9]. The coordinates and magnitude in the stars' B and V filters were extracted from the SIMBAD database.

No.	δ Scuti star	R.A. J2000 (hh:mm:ss)	Dec. J2000 (dd:mm:ss)	*B* (mag)	*V* (mag)	Possibility for observation at TNO[1]	Approximate highest altitude of the star (deg)
1	V367 Cam	04:40:55.19	+53:38:06.46	11.53	10.80	Yes	55
2	DY Her	16:31:17.95	+11:59:52.46	10.80	10.50	Yes	83
3	EH Lib	14:58:55.92	-00:56:53.01	10.09	9.83	Yes	72
4	SZ Lyn	08:09:35.75	+44:28:17.60	9.73	9.08	Yes	64
5	V593 Lyr	18:32:06.43	+40:35:56.52	12.39	11.66	Yes	68
6	V337 Ori	05:59:20.58	+20:02:07.53	11.79	11.43	Yes	88
7	GSC 1442-1358	12:13:40.78	+17:14:37.81	12.26	11.76	Yes	89
8	GSC 3428-1497	09:21:02.52	+49:05:53.93	9.55	9.29	Yes	59
9	GSC 3832-0152	11:48:42.07	+54:43:07.52	11.72	11.63	Yes	54
10	NSVS 11672463	21:51:52.32	+17:44:43.46	14.00	13.62	Yes	89

[1] TNO is the Thai National Observatory (98.4853°E, 18.5725°N) at Doi Inthanon, Chiang Mai, Thailand.

V593 Lyr (V593 Lyra, GSC 3109-00162, TIC 289325437; R.A. = $18^h\,32^m\,06.435^s$; Dec = +40° 35′ 56.517″) is a HADS star, which was first discovered by Wils et al. [10]. They reported that V593 Lyr has a pulsation period of 0.102145 d in the approximate magnitude range of 12.4-12.9 in the *B* filter. Recently, Gaia Early Data Release 3 (Gaia EDR3) reported the proper motion of μ_α= 0.806 ± 0.018 mas·year^{-1}, μ_δ= -6.808 ± 0.016 mas·year^{-1}, and parallax of 0.6855 ± 0.0141 mas. In 2012, Wils et al. published a list of 64 HADS and presented four values of maximum time of V593 Lyr [9]. Furthermore, there is not much scientific publication on this target compared to other HADS stars in the list.

In the present paper, we reported the new values of 28 times of maxima from 15 observational nights and the light curve and frequency analyses of the HADS V593 Lyr. The paper is organized as follows. Section 2 describes the materials and method. Section 3 presents the results and discussion, including the new light maximum time, the light curve behavior, and frequency analyses. Finally, section 4 reports the conclusions of the recent results of the study.

2. Materials and Methods

2.1 Data and Observations

The photometric data of V593 Lyr in the *V* filter (*V*) and clear filter (*CV*) were collected from the American Association of Variable Stars Observers international database (AAVSO), which is the world's largest and most extensive digital database of variable stars. The primary goal of the database is to organize observations and data of variable stars, made mainly by amateur astronomers from around the world, to assess their accuracy, process them, and make them accessible to students, teachers, educators, and researchers worldwide. The AAVSO is a non-profit international scientific and educational organization where professional, and amateur astronomers collaborate for variable star searching [11].

The scientific quality frames in the study consist of 2,968 frames collected from 15 observational nights in 2010–2021. The data were observed and published by professional and amateur astronomers from several institutes worldwide. The photometric data can be downloaded from the website of the AAVSO database: https://www.aavso.org/data-download. In addition, the HADS V593 Lyr can be observed in Thailand using telescopes at the Thai National Observatory (TNO), Doi Inthanon, Chiang Mai, Thailand. The observatory has been organized by the National Astronomical Research Institute of Thailand (NARIT). The best period for full-night observation at TNO is between the 12th of June and the 3rd of July, with the star's altitude of more than 30 degrees and considering the good sky conditions. The information on CCD observations in the study is presented in Table 2. The last column shows the times maximum light was collected in each observational night.

Table 2. The journal of CCD observations, the light maximum times of V593 Lyr were collected in 2010-2021.

No.	Date of Observation	Filter	Frames	Time Span (hours)	Duration time (HJD+2450000)	Observer code[1]	No. of Maxima
1	08/06/2010	*V*	257	6.8989	5356.60424 - 5356.89045	DKS	2
2	09/06/2010	*V*	295	6.9817	5357.60616 - 5357.89707	DKS	3
3	08/08/2010	*V*	129	3.6803	5782.40865 - 5782.56200	PXR	1
4	25/05/2012	*V*	247	2.8208	6073.39030 - 6073.50783	VMAE	2
5	14/06/2014	*V*	162	4.6494	6823.39120 - 6823.58493	VMAE	1
6	15/04/2015	*V*	221	5.9837	7128.40032 - 7128.64964	VMAE	3
7	12/10/2015	*V*	159	2.2189	7308.25315 - 7308.34561	DUBF	1
8	13/03/2016	*V*	130	5.2058	7461.49786 - 7461.71477	VMAE	2
9	09/08/2018	*V*	68	1.9879	8340.42803 - 8340.51086	VMT	1
10	09/10/2018	*V*	252	3.8326	8401.30103 - 8401.46072	SDWA	2
11	28/05/2020	*CV*	185	3.1950	8998.48036 - 8998.61349	PXR	2
12	03/08/2020	*V*	217	3.5236	9065.49594 - 9065.64275	DFS	2
13	28/05/2021	*CV*	113	4.8821	9363.36094 - 9363.56435	HMB	2
14	24/07/2021	*V*	324	7.1954	9420.31456 - 9420.61436	PMAK, DFS	2
15	30/07/2021	*V*	209	3.8680	9426.29290 - 9426.45407	PMAK	2
-	-	-	2968	66.8941	-	-	28

[1] The AAVSO observer codes: DKS = Shawn Dvorak, PXR = Roger Pickard, VMAE = Maarten Vanleenhove, DUBF = Franky Dubois, VMT = Tonny Vanmunster, SDWA = David Smith, PXR = Roger Pickard, DFS = Sjoerd Dufoer, HMB = Franz-Josef Hambsch, PMAK = Maksym Pyatnytskyy.

2.2 Analyses

During 15 observational nights of V593 Lyr from the AAVSO database, we measured 28 times of maximum light by Kwee and van Woerden fitting [12] on each time of light maximum using the Maxima astronomical program version 27. These 28 maxima and their errors are provided in Table 3. The new times of light maximum are crucial preliminary results to study period variation rate. The first and previous ephemeris for V593 Lyr [10] is:

$$HJD_{Max} = 2452084.4974\ (\pm 0.0003) + 0.1021497\ (\pm 0.0000002)E. \quad (1)$$

Table 3. The light maximum times of V593 Lyr and their accuracies.

No.	HJD (+2450000)	Error (days)	No.	HJD (+2450000)	Error (days)
1	5356.70600	0.00023	15	7461.63274	0.00021
2	5356.80834	0.00027	16	8349.43852	0.00021
3	5357.62547	0.00017	17	8401.32068	0.00020
4	5357.72749	0.00028	18	8401.42233	0.00011
5	5357.82995	0.00031	19	8998.49603	0.00022
6	5782.47251	0.00039	20	8998.59902	0.00024
7	6073.39804	0.00026	21	9065.50765	0.00013
8	6073.50031	0.00012	22	9065.61025	0.00031
9	6823.49497	0.00039	23	9363.38032	0.00042
10	7128.41547	0.00040	24	9363.48287	0.00040
11	7128.51770	0.00018	25	9420.38054	0.00011
12	7128.61984	0.00031	26	9420.58472	0.00013
13	7308.30322	0.00010	27	9426.30509	0.00012
14	7461.53114	0.00028	28	9426.40784	0.00031

We performed a frequency analysis for the light curves of V593 Lyr using the excellent and popular tool Period04 package software [13], based on the discrete Fourier analysis and the pre-whitening techniques. In this procedure, we selected large data strings with well-defined zero points and covered more than one complete cycle. Amplitudes of the light curves are presented as half of the peak-to-peak value. Assuming $mag(t)$ is the magnitude observed at a time t or a measurement of light variation from a star. The fitting formula used for the HADS light curves is in the form [5]:

$$mag(t) = Z + \sum_{i=1}^{n} A_i \sin\left[2\pi(\omega_i t + \emptyset_i)\right], \quad (2)$$

Where Z is zero-point, A_i is amplitude, ω_i is frequency, and $\emptyset_i$ is a phase of the i-th harmonic. Only frequencies that reach the criteria $A_i/\sigma_i > 4$ were used in the fitting [14-15]. Firstly, the dominant frequency was measured using terminal fitting in the Period04 software package. As a criterion for detecting a pulsation frequency, only the peak with S/N larger than four was selected in this procedure and a frequency in the range of 0-100 c/d. Then the residuals were examined for farther signals after removing the main frequency and its additional frequencies. If its S/N is higher than four, the process continues to detect a new frequency. On the other hand, if the value of the S/N is lower than four, the process is terminated [1], then significant frequencies and their analytical errors of the star are reported.

3. Results and Discussion

3.1 Light Curve Behavior

Figure 1 presents the differential magnitude light curve in the *V* and *CV* filters of 15 observational nights in 2010-2021. It shows that the synthetic light curves fit the observational data well. It suggests that the fundamental frequency and its harmonics can explain the pulsation behavior of V593 Lyr. The light variation of V593 Lyr in the *V*-filter is more than 0.3 magnitudes corresponding to the specific characteristics of HADS stars, which have high amplitudes of their light curves of more than 0.3 magnitudes in the *V*-band ($\Delta V \geq 0.3$ mag) [5, 16].

3.2 New Light Maximum Time

The study used adequate quality data from the Johnson *V* and *CV* filters. Based on a visual examination of the light curves, the data has no obvious bad points. The data set used for the Fourier analysis consists of 2,968 data points, covering a time base of 15 observational nights. The light maximum times of V593 Lyr and their errors are presented in Table 3. They are preliminary results for the period change rate (dP/dt) study in the future.

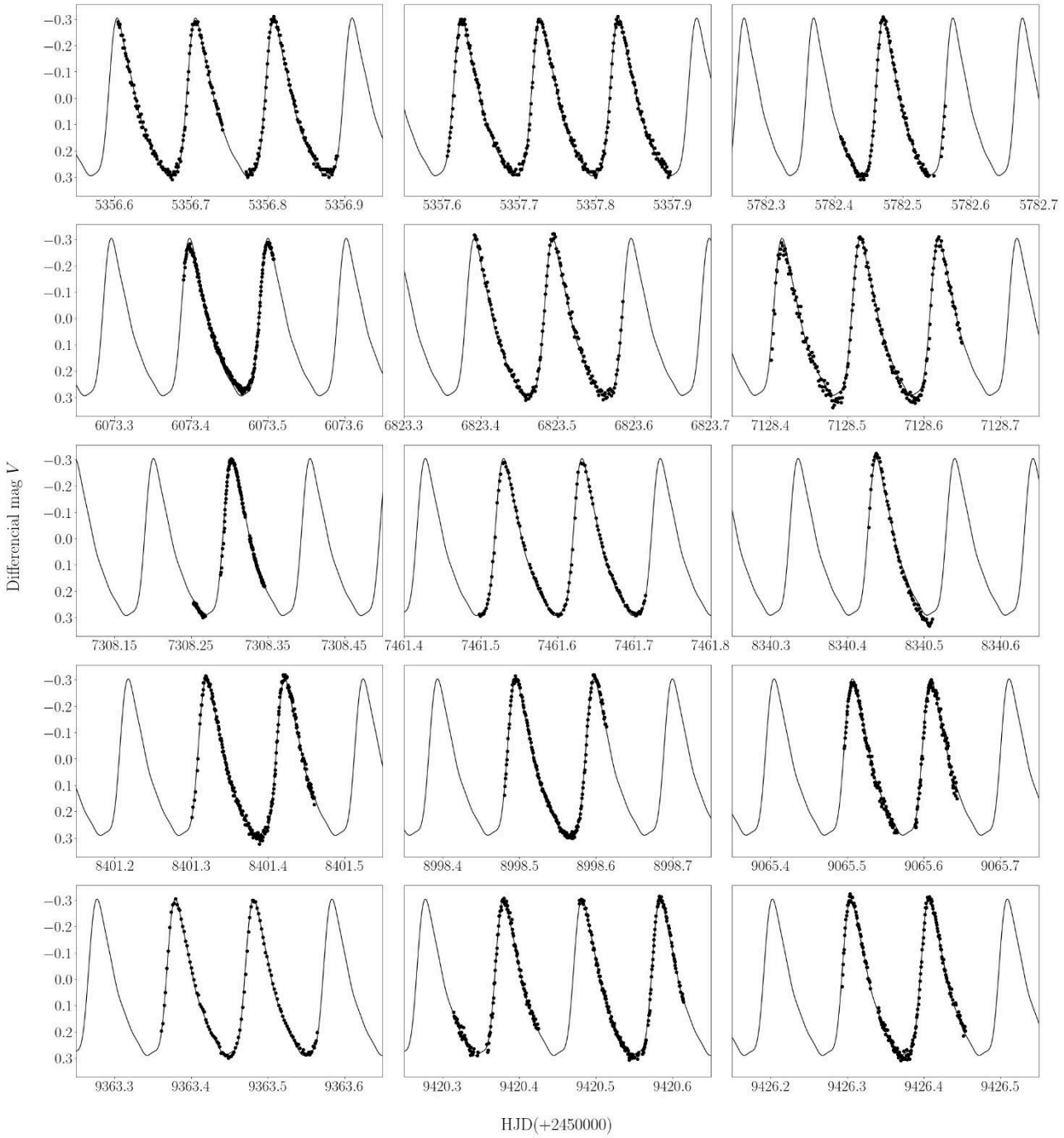

Figure 1. The observed and synthetic light curves in the *V* and *CV* bands of the high amplitude δ Scuti V593 Lyr. These sub-figures present the light curves from the total 15 observational nights. The points represent the observed light curve, and the solid curves show the synthetic light curves fitted with the five significant frequency solutions.

3.3 Frequency Analysis

From the frequency analysis of V593 Lyr, we found a fundamental frequency (f_0) and its four harmonic frequencies ($2f_0, 3f_0, 4f_0, 5f_0$) with the criterion of an S/N ratio larger than four. It was found that the fundamental frequency (f_0) of about 9.7894180 ± 0.0000002 d^{-1} corresponds to the main pulsation period of about 0.1021511 d or 2.4516268 hr, and the second to fifth harmonics of the fundamental frequency were also determined. Frequencies, amplitudes, and phases of the best-fitting sinusoids with their analytical errors are given in Table 4. The uncertainty values of frequency, amplitude, and phase were performed by the Monte

Carlo simulation contained in the Period04 software. After the fundamental frequency (f_0) was detected as the value of 9.7894180 ± 0.0000002 d^{-1}, and the pulsation period was calculated by dividing one over the frequency. Finally, we obtain the star fold's orbital phase diagram by the pulsation period value 0.1021511 d, as presented in Figure 2. The power spectrum of the high amplitude δ Scuti V593 Lyr is presented in Figure 3. The last column of Table 4 shows the frequency ratios between i-th harmonic relative to the fundamental frequency to confirm the relationship between the corresponding frequencies and the fundamental frequency.

Table 4. The results of frequency fitting to the light curves of V593 Lyr includes frequencies, amplitudes, phase, their errors, S/N value, and the ratio between harmonic and fundamental frequencies.

No.	ID	Frequency (d^{-1})	Amplitudes (mmag)	Phase (rad)	S/N	f_n/f_1
1	f_0	9.7894180 ± 0.0000002	259.5 ± 0.4	0.6383 ± 0.0002	121.43	1.0
2	$2f_0$	19.5788338 ± 0.0000005	95.0 ± 0.4	0.6794 ± 0.0006	88.88	2.0
3	$3f_0$	29.368248 ± 0.000001	38.0 ± 0.4	0.762 ± 0.002	57.19	3.0
4	$4f_0$	39.157671 ± 0.000002	19.2 ± 0.4	0.764 ± 0.003	27.80	4.0
5	$5f_0$	48.947098 ± 0.000005	9.5 ± 0.4	0.756 ± 0.006	15.82	5.0

In this study, only one dominant frequency and its four harmonics were detected with the criteria of an S/N of more than four. On the other hand, independent frequencies were not detected from the frequency analysis. It can be concluded that the HADS V593 Lyr pulsates in a multiple-frequency radial mode, which means it symmetrically increases and decreases in stellar radius during each pulsation period. This type of pulsation was also found in other HADS stars, for instance, GP And [5], V460 And [17], and YZ Boo [18]. In HADS stars, slow rotation is typically required for high-amplitude radial pulsation [19].

HADS stars are the H-R diagram's transitional objects between high-amplitude Cepheids and low-amplitude pulsating MS stars. They pulsate in one or several radial modes with high amplitudes [1], and about 0.24% of all δ Scuti stars are in our Milky Way Galaxy [20]. In addition to radial pulsations, several investigations indicate that low-amplitude nonradial modes may also be present in HADS stars.

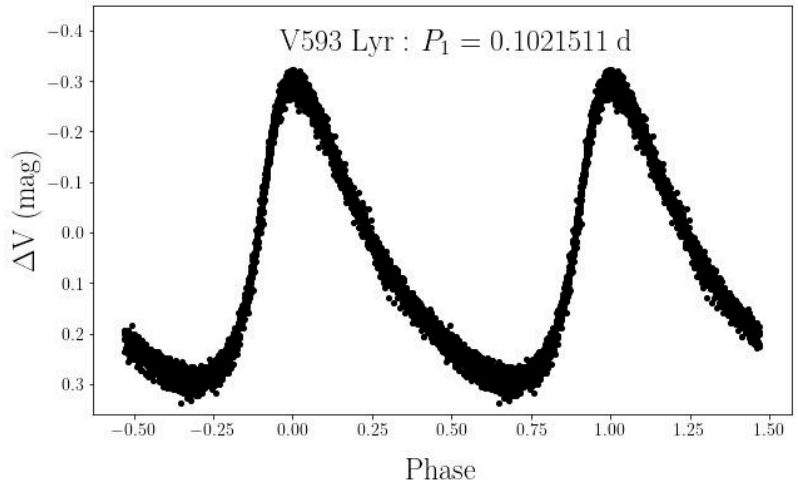

Figure 2. The orbital phase of V593 Lyr folded with the main period of 0.1021511 d.

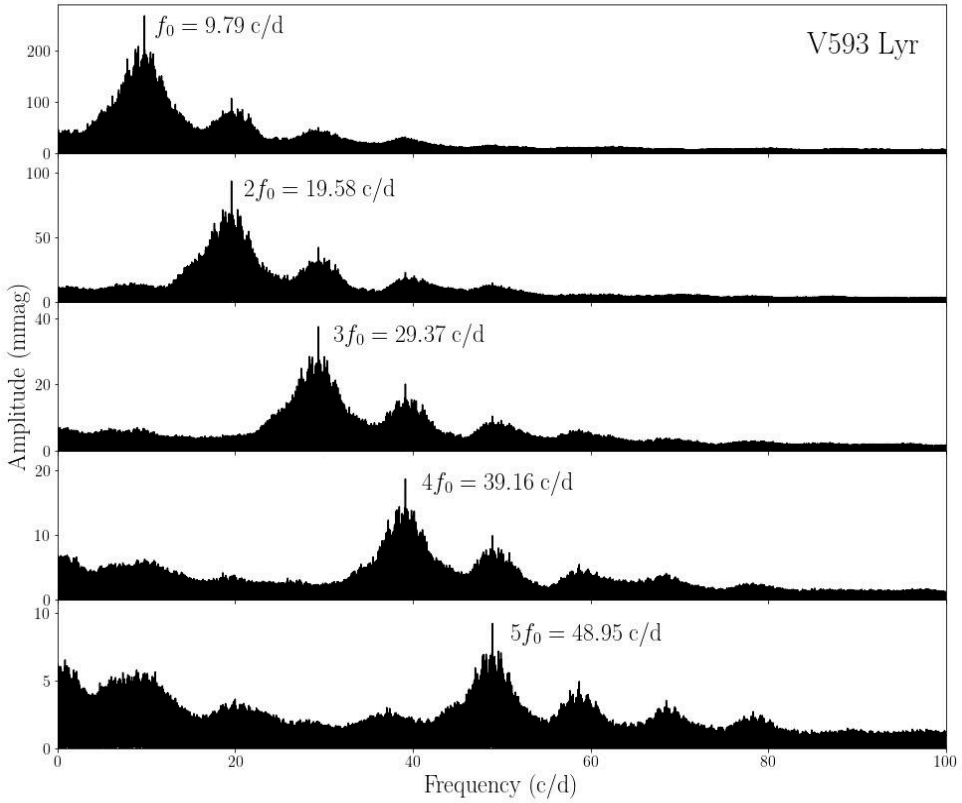

Figure 3. Power spectrum of the high amplitude δ Scuti V593 Lyr. The first top panel is a spectrum of the fundamental frequency. The lower four panels are spectrums of the second to fifth harmonics of the dominant frequency, respectively.

This step detects the second to fifth harmonics of the dominant frequency. From the value of the significant frequencies of the star, we can confirm that V593 Lyr is a HADS star with multiple frequency radial pulsation. It is limited research publications about V593 Lyr after the first discovery as GSC 3109-00162 in 2002 [10] and after the work of Wils et al. in 2012 [9]. Additional data from photometric and spectroscopic observations are requisite for more complete and accurate results regarding HADS stars. We intend to use the Thai National Telescope (TNT) and the Thai Regional Telescope (TRT) to observe HADS stars. With these facilities in Thailand, we can observe many HADS targets (see Table 1), collect a large amount of data to obtain highly accurate ground-based observations, and gather photometric and spectroscopic data for further research.

4. Conclusions

The new time-series CCD observations of V593 Lyr were collected using AAVSO international database covering 15 nights from June 2010 until July 2021. We measured 28 new light maximum times for V593 Lyr as preliminary results for the period change rate study in the future. In frequency analysis, it was found that the dominant frequency of V593 Lyr of about 9.7894180 ± 0.000002 d^{-1} corresponds to the pulsation period of 0.1021511 d.

5. Acknowledgements

We gratefully acknowledge the contributions made by observers worldwide to the American Association of Variable Stars Observers (AAVSO) international database used in this research to study δ Scuti variable stars. We thank the observers of the Working Group on Variable Stars of the Belgian Vereniging Voor Sterrenkunde (VVS, Society for Astronomy). This research used information from the SIMBAD database, operated by CDS in Strasbourg, France, and the NASA Astrophysics Data System. Period04 was used in our frequency analysis.

Author Contributions: Conceptualization, C.N.; methodology, C.N. and P.T.; software, P.T.; formal analysis, C.N., P.T. and M.N.; investigation, C.N., P.T. and M.N.; writing—original draft preparation, C.N., M.N.; writing—review and editing, C.N., P.T. and M.N.

Funding: This research received no external funding.

Conflicts of Interest: The authors declare no conflict of interest.

References

[1] Netzel, H.; Pietrukowicz, P.; Soszynski, I.; Wrona, M. Frequency analysis of δ Scuti stars towards the Galactic bulge. *Mon. Not. R. Astron*. 2021, *510(2)*, 1748–1764.

[2] Uytterhoeven, K.; Moya, A.; Grigahcène, A.; Guzik, J.A.; Gutiérrez-Soto, J.; Smalley, B.; Handler, G.; Balona, L.A.; Niemczura, E.; Fox Machado, L.; Benatti, S.; Chapellier, E.; Tkachenko, A.; Szabó, R.; Suárez, J.C.; Ripepi, V.; Pascual, J.; Mathias, P.; Martín-Ruíz, S.; Lehmann, H.; Jackiewicz, J.; Hekker, S.; Gruberbauer, M.; García, R.A.; Dumusque, X.; Díaz-Fraile, D.; Bradley, P.; Antoci, V.; Roth, M.; Leroy, B.; Murphy, S.J.; De Cat, P.; Cuypers, J.; Kjeldsen, H.; Christensen-Dalsgaard, J.; Breger, M.; Pigulski, A.; Kiss, L. L.; Still, M.; Thompson, S.E.; Van Cleve, J. The Kepler characterization of the variability among A- and F-type stars I. General overview. *Astron. Astrophys.* 2011, *534*, A125.

[3] Baglin, A.; Breger, M.; Chevalier, C.; Hauck, B.; Le Contel, J.M.; Sareyan, J.P.; Valtier, J.C. Delta Scuti stars. *Astron. Astrophys*. 1973, *23*, 221–240.

[4] Chang, S.W.; Protopapas, P.; Kim, D.W.; Byun, Y.I. Statistical properties of Galactic δ Scuti stars: revised. *Astron. J.* 2013, *145*, 132.

[5] Zhou, A.Y.; Jiang, S.Y. Period and amplitude variability of the high-amplitude δ Scuti star GP Andromedae. *Astron. J.* 2011, *142*, 100.

[6] Rodriguez, E.; Lopez-Gonzalez, M.J. SX Phe stars in globular clusters. *Astron. Astrophys.* 2000, *359*, 597–600.

[7] Dziembowski, W. A.; Pamyatnykh, A. A. *Astron. Astrophys.* 1991, *248*, L11–L14

[8] Aerts, C.; Christensen-Dalsgaard, J.; Kurtz, D.W. A*steroseismology*, 1st ed.; Springer Dordrecht, 2010; 1–866.

[9] Wils, P.; Panagiotopoulos, K.; Van Wassenhove, J.; Ayimamitis, A.; Nieuwenhout, F.; Robertson, C.W.; Vanleenhove, M.; Hambsch, F.J.; Hautecler, H.; Pickard, R.; Baillien, A.; Staels, B.; Kleidis, S.; Lampens, P.; Van Cauteren, P. Photometry of high-amplitude Delta Scuti stars. *Inf. Bull. Var. Stars.* 2012, *6015*, 1–8.

[10] Wils, P.; Van Cauteren, P.; Groenendaels, R. The high amplitude Scuti variable star GSC 3109-00162. *Inf. Bull. Var. Stars.* 2002, 142, 54–56.

[11] Percy, J.R.; Mattei, J.A. The AAVSO database of variable star observations. *Astrophys. Space Sci*. 1993, *210*, 137–138.

[12] Kwee, K.K.; van Woerden, H. A method for computing accurately the epoch of minimum of an eclipsing variable. *Bull. Astron. Inst. Netherlands* 1956, 12, 327–330.

[13] Lenz, P.; Breger, M. Period04 user guide. *Comm. in Asteroseismology* 2005, *146*, 53-136.

[14] Breger, M.; Stich, J.; Garrido, R.; Martin, B.; Jiang, S.Y.; Li, Z.P.; Hube, D.P.; Ostermann, W.; Paparo, M.; Scheck, M. Nonradial pulsation of the Delta-Scuti Star Bu-Cancri in the Praesepe cluster. *Astron. Astrophys* 1993, *271*, 482–486.

[15] Kuschnig, R.; Weiss, W.W.; Gruber, R.; Bely, P.Y.; Jenkner, H. Microvariability survey with the Hubble space telescope fine guidance sensors: exploring the instrumental properties. *Astron. Astrophys* 1997, *328*, 544–550.

[16] Rodriguez, E.; Breger, M. δ Scuti and related stars: Analysis of the R00 Catalogue. *Astron. Astrophys* 2001, 366, 178-196.

[17] Alton, K. B.; Stępień, K. CCD Photometry, light curve deconvolution, period analysis, kinematics, and evolutionary status of the HADS variable V460 Andromedae. *JAAVSO* 2019, *47*, 53–65.

[18] Abdel-Sabour, M.; Nouh, M.I.; Ata, S.; Darwish, M. Frequency and photometric analysis of the short period pulsating star YZ Boo. *NRIAG J. Astron. Geophys.* 2021, *10*, 416–422.

[19] Breger, M. Nonradial and radial period changes in the δ Scuti star 4 CVn I. 700+ nights of photometry. *Astron. Astrophys* 2016, *592*, A97.

[20] Lee, Y.H.; Kim, S.S.; Shin, J.; Lee, J. Incidence of high-amplitude δ Scuti-type variable stars. *Publ. Astron. Soc. Japan* 2008, 60, 551–555.