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Three new δ Scuti stars in Cygnus

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I present my discovery and CCD observations of three new small-amplitude δ Scuti (DSCTC) stars. Two of them demonstrate multiperiodic pulsations. The paper contains detected frequencies, light curves, finding charts, and other relevant information.

1 Introduction

During observations of a field in Cygnus, Kryachko et al. (2010) discovered several new variable stars. Here I report three additional new small-amplitude δ Scuti (DSCTC) stars in the same field. The new variable stars are listed in Table 1. Their coordinates were drawn from the Gaia DR3 catalog (Gaia Collaboration, 2022). None of these stars are currently contained in the AAVSO Variable Star Index (VSX). However, they are marked VARIABLE in the Gaia DR3 catalog. Table 1 also presents mean Gaia DR3 G magnitudes; they are needed for reference because our light curves (see below) are plotted in magnitude differences.

Table 1. New Variable Stars

No.	Star	RA, J2000.0	Dec, J2000.0	G
1	USNO-A2.0 1275-14987520	$21^h12^m19\overset{s}{.}130$	$+40°25'52\overset{''}{.}11$	$13\overset{m}{.}07$
2	USNO-A2.0 1275-15001392	21 12 36.142	+40 41 00.66	12.82
3	USNO-A2.0 1275-15124267	21 15 10.341	+40 37 01.05	13.77

2 Observations

Our observations were carried out at the Astrotel-Caucasus observatory using the 0.3-m Ritchey-Chretien telescope, equipped with an Apogee Alta U9000 CCD camera, and at the Caucasian Mountain Observatory (CMO) of M.V. Lomonosov Moscow State University, see Shatsky et al. (2020), using the 0.25-m remote controlled Ritchey-Chretien telescope, equipped with a SBIG STXL-6303e CCD camera and a V filter. The detailed information about observing sets is given in Table 2.

For basic reductions for dark current, flat fields, and bias, we used IRAF routines and proprietary software TheSkyX^{TM} by Software Bisque Inc. For photometry of new pulsating stars, we applied VaST software by Sokolovsky and Lebedev (2018). All times in this paper are expressed in terrestrial time in accordance with IAU recommendations (resolution B1 XXIII IAU GA), with heliocentric corrections applied. Detailed information about photometrical measurements of each star is given in Table 3.

To derive periods, we use Period04 software by Lenz and Breger (2005) that implements discrete Fourier transform and is very suitable for analysis of sine-shaped light curves of multiperiodic pulsating variable stars.

3 Results

3.1 USNO-A2.0 1275-14987520

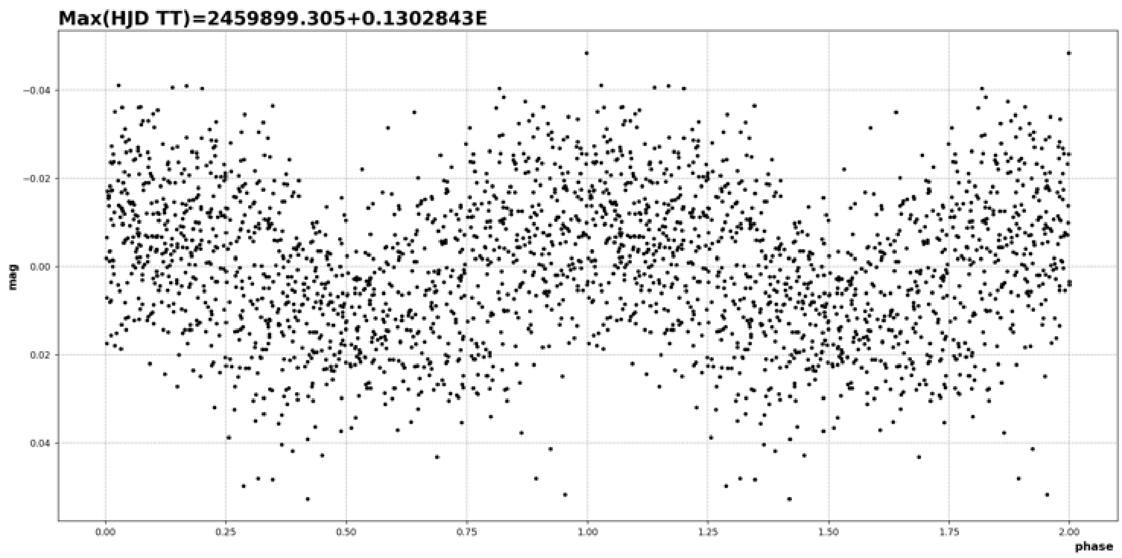

Figure 1. Phased light curve of USNO-A2.0 1275-14987520.

Table 2. Observing sets

No.	Telescope	CCD Camera	Interval of observations JD 245...	Frames	Filter	Exposure, seconds
1	0.3 m, 1/7.8	Apogee Alta U9000	4958 – 4993	630	unfiltered	300
2	0.3 m, 1/7.8	Apogee Alta U9000	5315 – 5450	719	*V*	300
3	0.3 m, 1/7.8	Apogee Alta U9000	6586 – 6604	706	*V*	300
4	0.25 m, 1/8	SBIG STXL-6303e	9841 – 9948	667	*V*	600

Table 3. Photometric measurements

No.	Interval of observations JD 245...	USNO-A2.0 1275-14987520	USNO-A2.0 1275-15001392	USNO-A2.0 1275-15124267	Filter
1	4958 – 4993	459	422	630	unfiltered
2	5315 – 5450	190	719	710	*V*
3	6586 – 6606	0	615	706	*V*
4	9841 – 9948	612	626	667	*V*
	Total	**1261**	**2382**	**2713**	

Observations of this star show changes in the level of maximum brightness. To clarify the star's variability features, we obtained additional observations at the Astrotel Caucasus observatory and, after its closure, at the Caucasian Mountain observatory. In total, we collected only 1261 observations between JD 2454958 and JD 2459948, because this star was outside the field of view during our observing set No. 3 (see Table 3). All these observations have sufficient accuracy for period analysis. Using Period04 software, we derived the following light elements:

$$\text{Max HJD(TT)} = 2459899.305 + 0\overset{\text{d}}{.}1302843 \times E.$$

Unfortunately, we were not able to detect multiperiodicity, possibly because the secondary oscillation's amplitude is within the accuracy of our photometry. The phased light curve of USNO-A2.0 1275-14987520 is presented in Fig 1. Its finding chart, based on POSS2 red plate, is shown in Fig. 2.

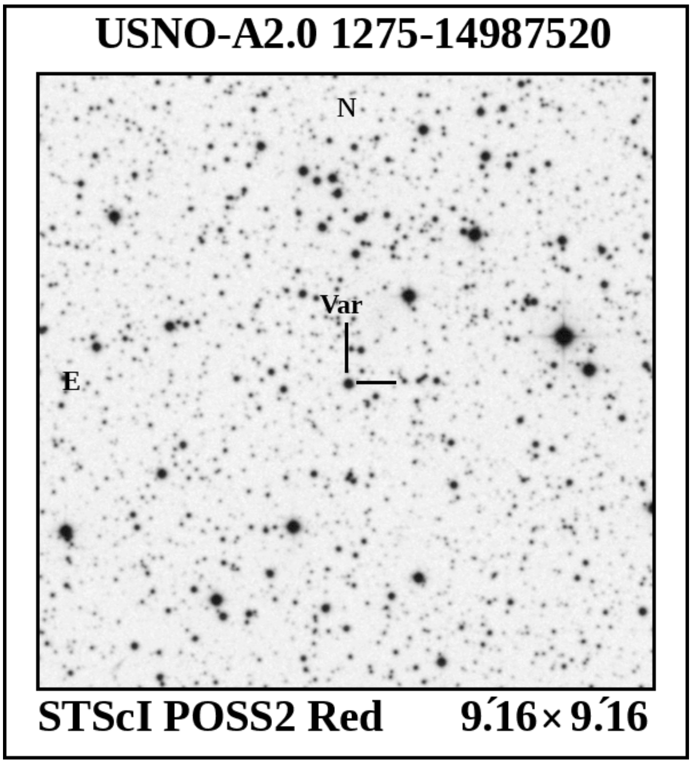

Figure 2. A finding chart for USNO-A2.0 1275-14987520.

3.2 USNO-A2.0 1275-15001392

All four observing sets reveal rapid variations at a time scale of about $0\overset{\text{d}}{.}1$ and with a peak-to-peak amplitude about $0\overset{\text{m}}{.}08$. We searched for periodic signals in the observations using Period04 software in the frequency range between 3 and 20 cycles per day that was selected following recommendations by Breger (2000). Two apparently significant frequencies were detected; their parameters corresponding to the equation

$$\Delta m(t) = \sum A_i \sin(2\pi(f_i t + \Phi_i)), \tag{1}$$

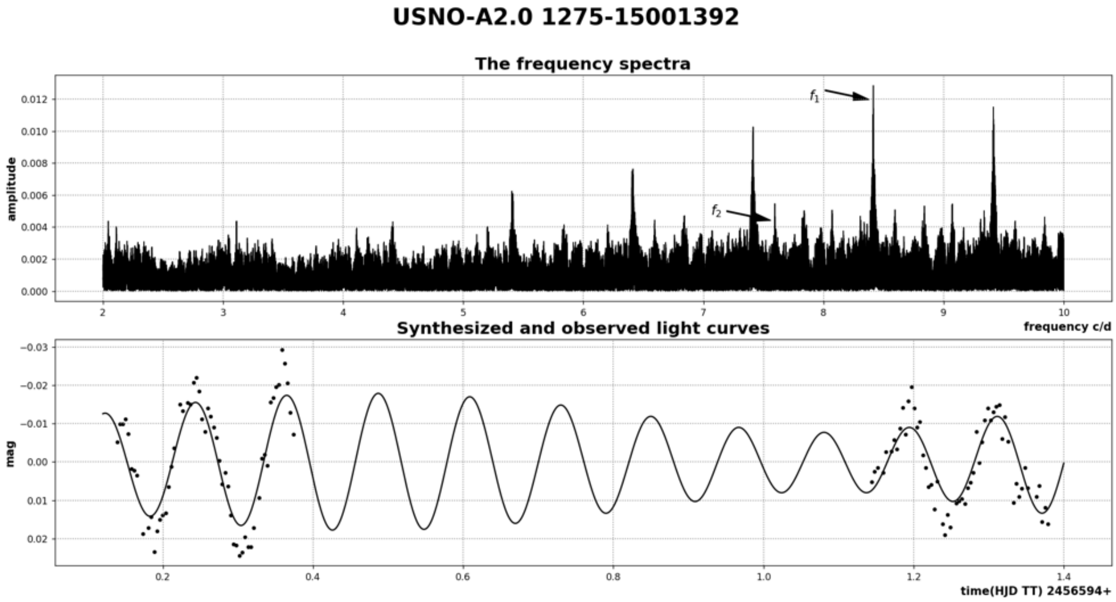

Figure 3. Frequency spectra and light curve of USNO-A2.0 1275-15001392. In the bottom panel, the solid curve is the synthesized light curve and dots are observed data points.

determined by least squares, are collected in Table 4.

Figure 3 presents the amplitude spectrum of USNO-A2.0 1275-15001392 and its theoretical light curve (solid curve) with superposed data points corresponding to individual observations. Light curve variations are easy to notice, they are reproduced with the model rather well. The finding chart based on POSS2 red plate is presented in Fig. 4.

3.3 USNO-A2.0 1275-15124267

The set of observations obtained for this star demonstrates rapid variations with an amplitude not exceeding $0\overset{\mathrm{m}}{.}12$. The sufficient number of available measurements and relatively high amplitude made it possible to identify three frequencies, presented in Table 5, with notation corresponding to eq. 1. Fig. 5 presents the amplitude spectrum of USNO-A2.0 1275-15124267 and its theoretical light curve (solid curve) with superposed data points corresponding to individual observations. The finding chart, based on POSS2 red plate, is shown in Fig. 6.

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Table 4. Detected frequencies of USNO-A2.0 1275-15001392

	Frequency, c/d	Φ	Amplitude, mag
f_1	8.4137218	0.173387	0.0128
f_2	7.5947267	0.947497	0.0051

Table 5. Detected frequencies of USNO-A2.0 1275-15124267

	Frequency, c/d	Φ	Amplitude, mag
f_1	7.3473022	0.911653	0.0220
f_2	7.6409009	0.663722	0.0208
f_3	7.4684716	0.187621	0.0144

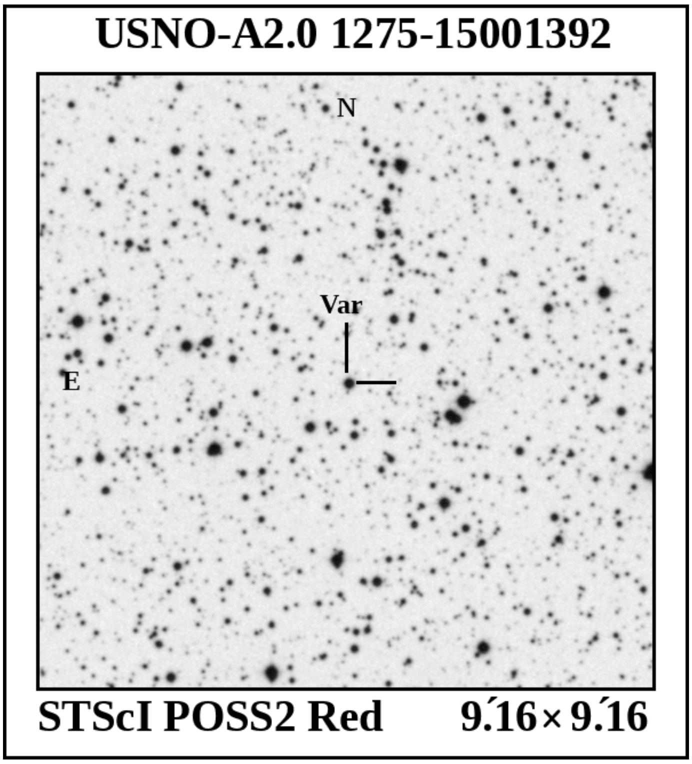

Figure 4. A finding chart for USNO-A2.0 1275-15001392.

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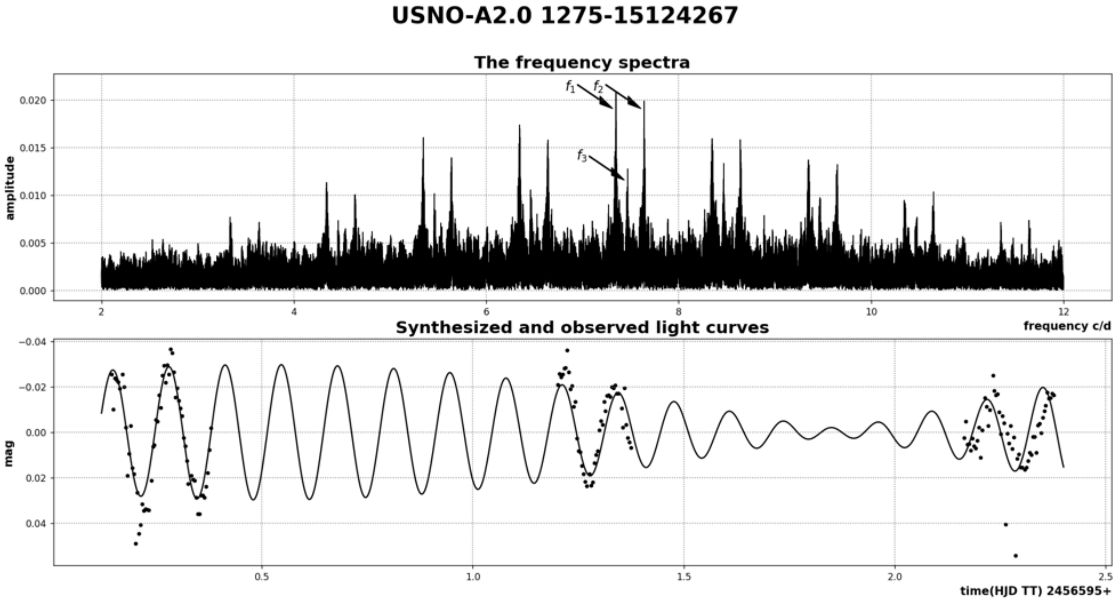

Figure 5. Frequency spectra and light curve of USNO-A2.0 1275-15124267. In the bottom panel, the solid curve is the synthesized light curve and dots are observed data points.

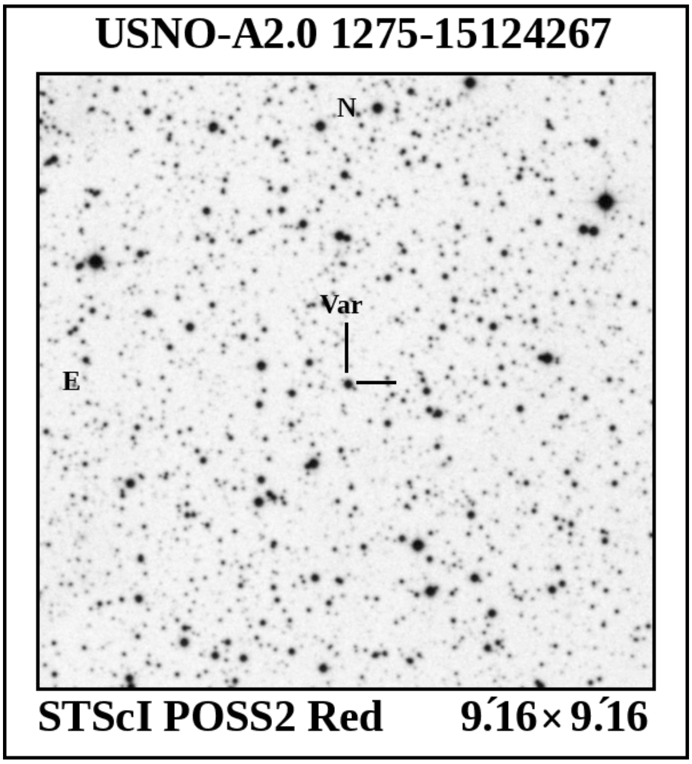

Figure 6. A finding chart for USNO-A2.0 1275-15124267.