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Two New δ Scuti Stars in Hercules

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

1 Introduction

During observations of a field of the transient 2023lmj in Hercules (see Sokolovsky et al., 2023), I discovered two new small-amplitude δ Scuti (DSCTC) stars that demonstrate multiperiodic pulsations. 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, see Gaia Data Release 3 (Gaia DR3), Part 4, Variability (2022).

Table 1. New Variable Stars

No.	Star	RA, J2000.0	Dec, J2000.0	V
1	USNO-A2.0 0975-13540472	$18^h54^m22^s.082$	$+14°55'53''.49$	$13^m.27 - 13^m.32$
2	USNO-A2.0 1050-12146993	18 54 24.577	+15 04 26.11	14. 08 – 14. 19

2 Observations and magnitude calibration

Our observations were carried out 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 with a V filter. A total of 978 images with 600-s exposures were obtained on JD 2460120 – 2460257.

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 & 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. For magnitude calibration in V band, we apply data from the Gaia DR3 catalogue. We use single, relatively bright stars, but with no saturation of pixels for our CCD camera, without close neighbors, and not demonstrating brightness variations during the time interval of our observations. Detailed information about our calibration stars is collected in Table 2. Uncertainties in the σ_V column were derives from our photometry; Gaia G, G_{BP}, and G_{RP} magnitudes were drawn from the corresponding catalog. Magnitudes in the Calc. V column were obtained using the equation:

$$Calc.\ V = Gaia\ G - [-0.02704 + 0.01424 \times (G_{BP} - G_{RP}) - 0.2156 \times (G_{BP} - G_{RP})^2 + 0.01426 \times (G_{BP} - G_{RP})^3], \quad (1)$$

which is based on table 5.9 of the Gaia Data Release 3, Documentation release 1.2 (https://gea.esac.esa.int/archive/documentation/GDR3/).

Table 2. Magnitudes of calibration stars

GSC	σ_V	Gaia			Calc. V
		G	G_{BP}	G_{RP}	
01051-01179	0.005	12.7355	12.9894	12.3245	12.8442
01051-01491	0.004	12.0755	12.8689	11.2027	12.6114
01585-00306	0.005	11.9655	12.9243	11.0048	12.6587
01584-00111	0.005	12.2554	12.7376	11.6132	12.5187
01051-01757	0.004	12.1621	12.5855	11.5643	12.3843
01051-00969	0.004	11.8089	12.5785	12.5785	12.3215

To derive periods, we use Period04 software by Lenz & 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 0975-13540472

Observations of this star show rapid variations at a time scale of about $0^{d}.05$ with a peak-to-peak amplitude about $0^{m}.05$. 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). Four apparently significant frequencies were detected; their parameters corresponding to the equation:

$$\Delta m(t) = \sum A_i \sin(2\pi(f_i t + \Phi_i)), \quad (2)$$

determined by least squares, are collected in Table 3.

Table 3. Detected frequencies of USNO-A2.0 0975-13540472

	Frequency, c/d	Φ	Amplitude, mag
f_1	18.52586	0.165096	0.0092
f_2	18.44123	0.173702	0.0078
f_3	16.33431	0.080947	0.0035
f_4	19.50166	0.341614	0.0012

Figure 1 presents the amplitude spectrum of USNO-A2.0 0975-13540472 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. 2.

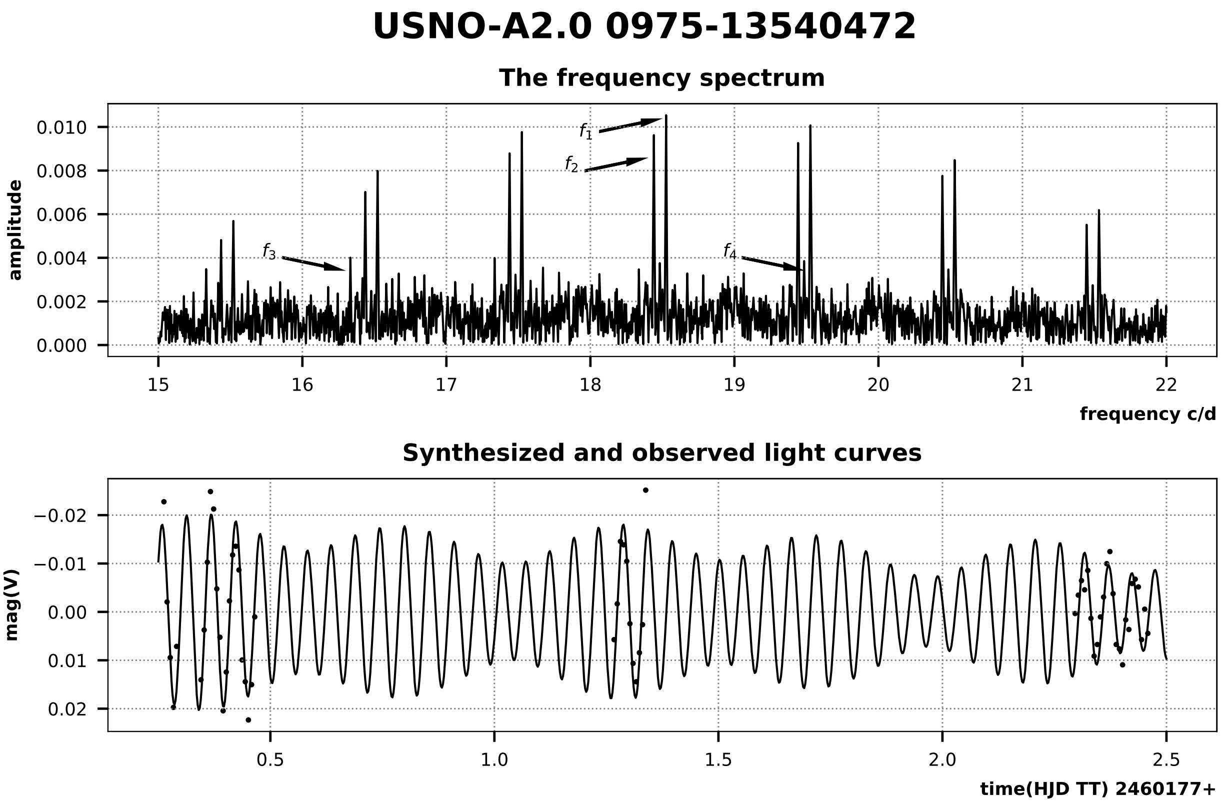

Figure 1. Frequency spectra and light curve of USNO-A2.0 0975-13540472. In the bottom panel, the solid curve is the synthesized light curve and dots are observed data points.

The V-filter phased light curve of USNO-A2.0 0975-13540472 with the following light elements:

$$\text{Max HJD(TT)} = 2460177.2554 + 0\overset{\text{d}}{.}053979 \times E$$

is presented in Fig. 3.

3.2 USNO-A2.0 1050-12146993

Photometric measurements of this star reveal rapid variations at a time scale of about $0\overset{\text{d}}{.}1$ and with a peak-to-peak amplitude about $0\overset{\text{m}}{.}1$. To search for periodic signals in the observations, we applied Period04 software in the frequency range between 3 and 20 cycles per day that had been selected following recommendations by Breger (2000). Three apparently significant frequencies were detected; their parameters, corresponding to Equation 2 determined by least squares, are collected in Table 4.

Table 4. Detected frequencies of USNO-A2.0 1050-12146993

	Frequency, c/d	Φ	Amplitude, mag
f_1	9.51668	0.235789	0.0241
f_2	5.65634	0.016710	0.0096
f_3	6.47599	0.250858	0.0085

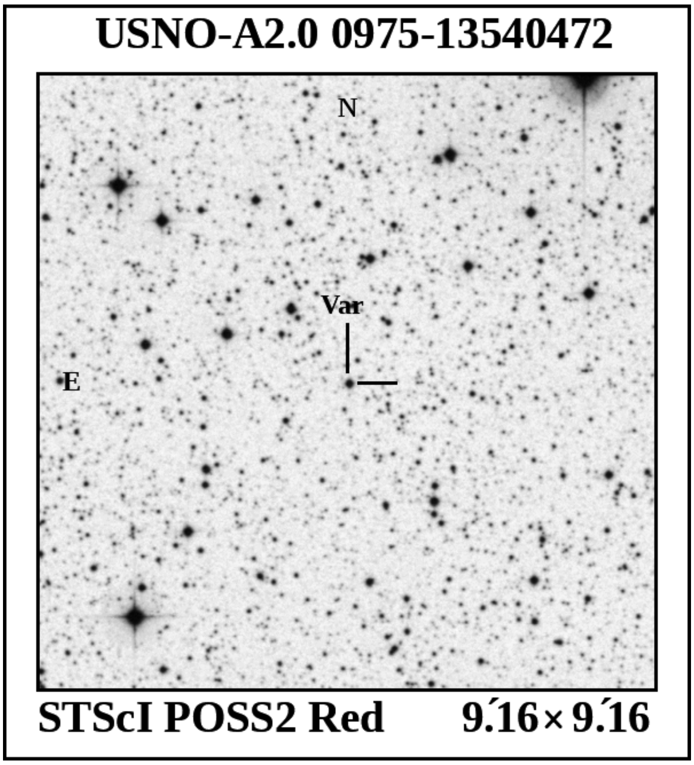

Figure 2. A finding chart for USNO-A2.0 0975-13540472.

Figure 4 presents the amplitude spectrum of USNO-A2.0 1050-12146993 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. 5. The V-filter phased light curve of USNO-A2.0 1050-12146993 with the following light elements:

$$\text{Max HJD(TT)} = 2460162.4536 + 0\overset{\text{d}}{.}105079 \times E$$

is presented in Fig. 6.

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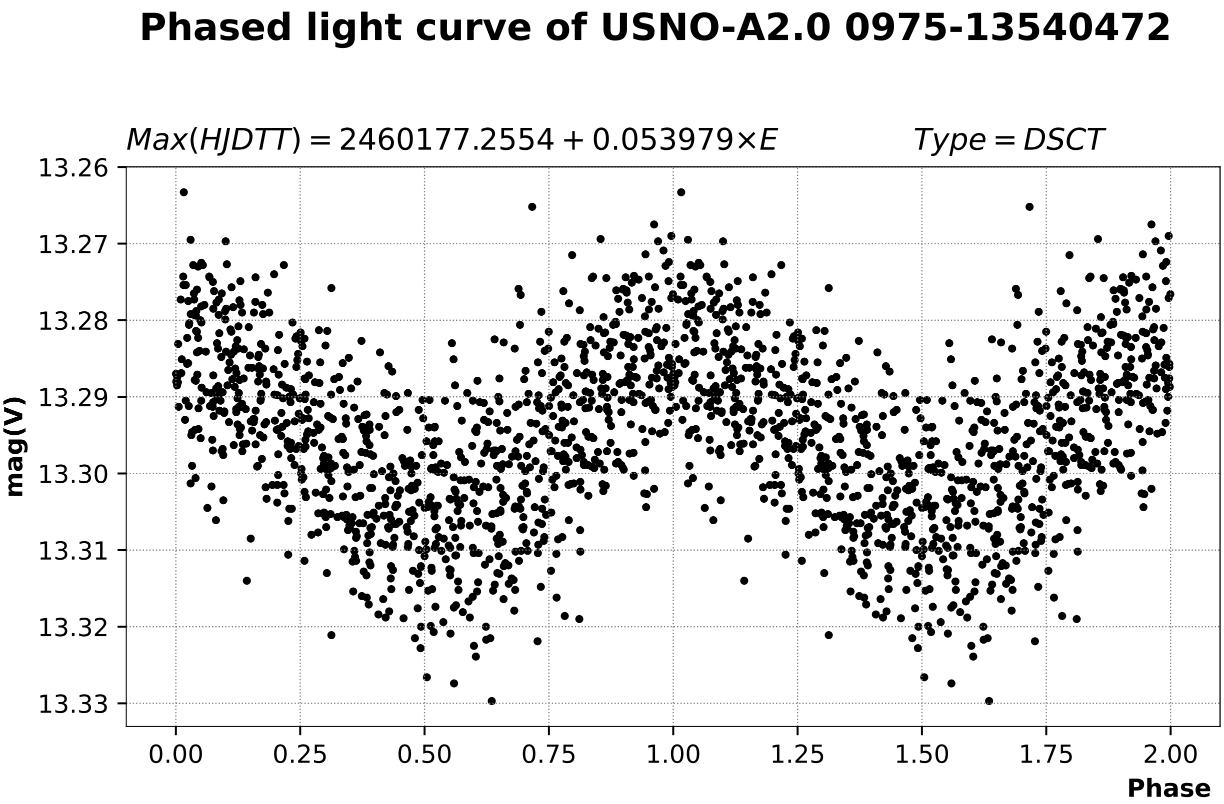

Figure 3. Phased light curve of USNO-A2.0 0975-13540472.

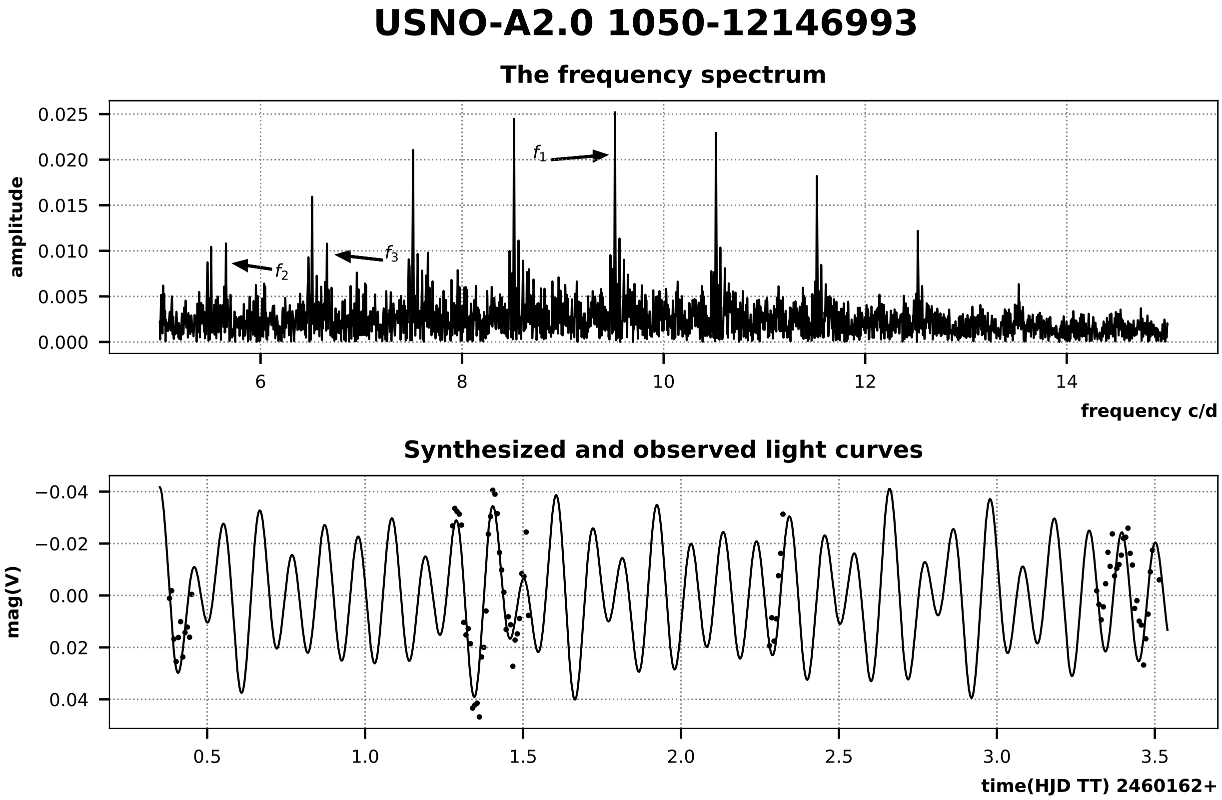

Figure 4. Frequency spectra and light curve of USNO-A2.0 1050-12146993. In the bottom panel, the solid curve is the synthesized light curve and dots are observed data points.

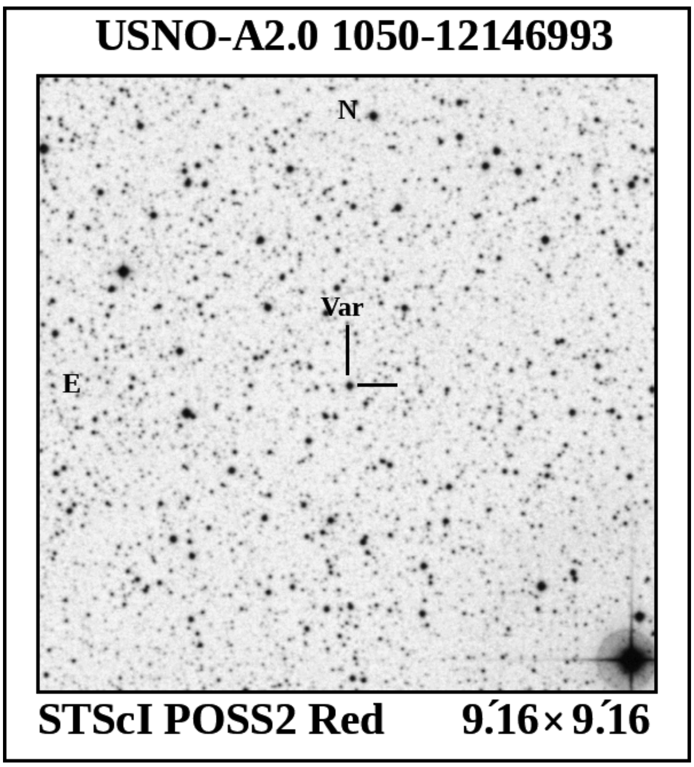

Figure 5. A finding chart for USNO-A2.0 1050-12146993.

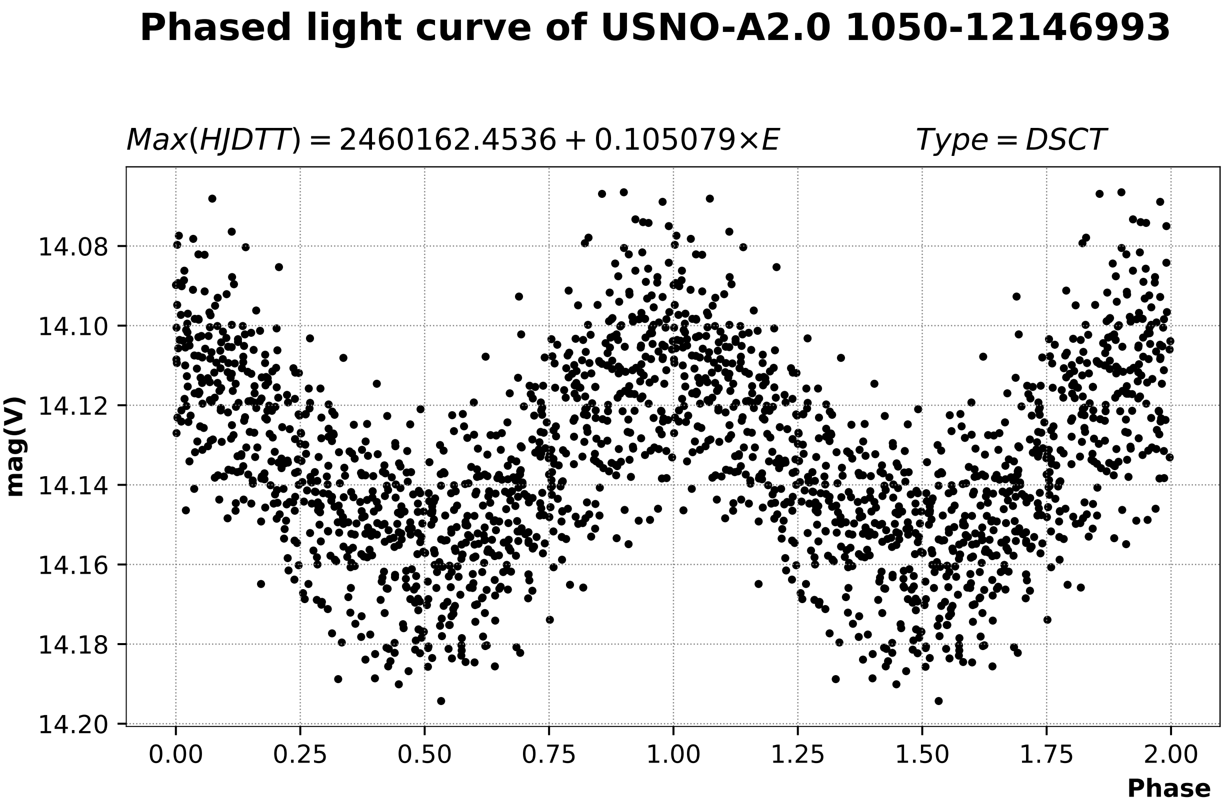

Figure 6. Phased light curve of USNO-A2.0 1050-12146993.