Peremennye Zvezdy (*Variable Stars*) **43**, No. 3, 2023

Received 10 April; accepted 27 April.

DOI: 10.24412/2221-0474-2023-43-20-26

Two new δ Scuti stars in Auriga

A. Samokhvalov

Surgut, Russia, e-mail: sav@surgut.ru

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

1 Introduction

During observations of a field in Auriga, Kryachko et al. (2011) discovered several new variable stars. Here I report two 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. New Variable Stars

No.	Star	RA, J2000.0	Dec, J2000.0	V	R_c
1	TYC 2414-127-1	$05^{\rm h}58^{\rm m}16\overset{\rm s}{.}689$	$+35°11'20\overset{''}{.}15$	$11\overset{\rm m}{.}81 - 11\overset{\rm m}{.}85$	$11\overset{\rm m}{.}72 - 11\overset{\rm m}{.}75$
2	USNO-A2.0 1200-04164745	05 59 34.451	+35 11 15.38	15.18 – 15.28	14.78 – 14.90

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 V and R_c filters. Information about the observing sets is given in Table 2.

Table 2. Observing sets

No.	Interval of observations JD 245...	Frames	Filter	Exposure, seconds
1	9257 – 9305	356	R_c	300
2	9875 – 9987	1156	V	600

For basic reductions for dark current, flat fields, and bias, we used IRAF routines and proprietary software TheSkyX$^{\rm TM}$ 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.

For magnitude calibration in the V band, we use data of the Tycho2 catalogue, and in the R_c band, Gaia DR3. We use single, relatively bright stars that do not produce saturation of pixels of our CCD camera, have no close neighbors, and do not demonstrate variability on the time interval of our observations. Detailed information about calibration stars is given in Table 3. Values in the σ_V and σ_{Rc} columns were obtained from our photometry; Tycho B, Tycho V, Gaia G, G_{BP}, and G_{RP} were drawn from the corresponding catalogues. Magnitudes in the Calc. V column were obtained using the equation:

$$Calc.\ V = Tycho\ V - 0.09 \times (Tycho\ B - Tycho\ V), \quad (1)$$

described in eq. 1.3.20 in Hipparcos and Tycho Catalogue (ESA, 1997).

To calculate magnitudes in the Calc. R_c column, we use the equation:

$$Calc.\ R_c = Gaia\ G - 0.02275 + 0.3961 \times (G_{BP} - G_{RP}) - 0.1243 \times (G_{BP} - G_{RP})^2 - 0.01396 \times (G_{BP} - G_{RP})^3 + 0.003775 \times (G_{BP} - G_{RP})^4, \quad (2)$$

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

Table 3. Magnitudes of calibration stars

Tycho name	σ_V	σ_{R_c}	**Tycho**		**Calc.** V	**Gaia**			**Calc.** R_c
			B	V		G	G_{BP}	G_{RP}	
TYC-2414-97-1	0.004	0,004	13.272	12.331	12.246	12.6844	12.7066	12.1160	12.5190
TYC-2414-128-1	0.006	0.005	13.511	12.258	12.145	12.0363	12.4114	11.4907	11.8079
TYC-2427-89-1	0.006	0.005	11.980	11.703	11.678	11.9705	12.1948	11.5968	11.8033
TYC-2427-185-1	0.007	0.005	12.371	11.784	11.731	11.5736	11.8105	11.1838	11.3998
TYC-2427-495-1	0.006	0.005	12.521	11.910	11.855	11.5991	11.9529	11.0720	11.3766
TYC-2427-497-1	0.006	0.006	13.176	12.830	12.799	12.1947	12.5411	11.6725	11.9742
TYC-2427-623-1	0.006	0.005	12.212	11.994	11.974	11.7696	12.0481	11.3194	11.5741
TYC-2427-1263-1	0.006	0.004	12.460	11.896	11.845	11.9711	12.1749	11.6178	11.8138

Information on photometric measurements available for the two variable stars is given in Table 4. An archive of all observations is available online in the html version of this paper.

Table 4. Number of photometric measurements

No.	**Interval of observations JD 245...**	**TYC 2414-127-1**	**USNO-A2.0 1200-04164745**	**Filter**
1	9257 – 9305	355	355	R_c
2	9875 – 9987	1155	1155	V
Total		**1510**	**1510**	

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 TYC 2414-127-1

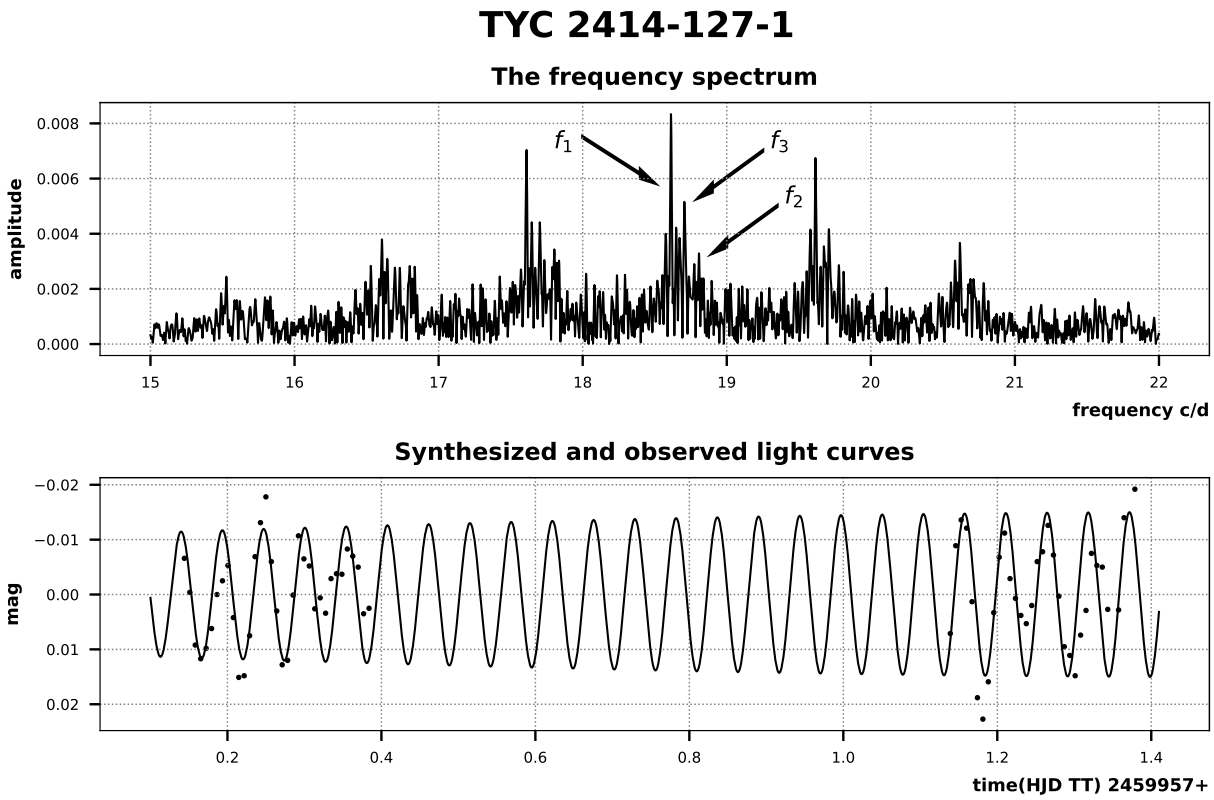

Figure 1. Frequency spectrum and light curve of TYC 2414-127-1. In the bottom panel, the solid curve is the synthesized light curve and dots are observed data points.

Observations of this star show rapid variations at a time scale of about $0^{\rm d}.05$ with a peak-to-peak amplitude about $0^{\rm m}.04$. We searched for periodic signals in the observations using Period04 software in the frequency range between 3 and 20 cycles per day, selected following recommendations by Breger (2000). Three apparently significant frequencies were detected; their parameters corresponding to the equation:

$$\Delta m(t) = \sum A_i \sin(2\pi(f_i t + \Phi_i)), \tag{3}$$

determined by least squares, are collected in Table 4.

Table 4. Detected frequencies of TYC 2414-127-1

	Frequency, c/d	**Φ**	**Amplitude, mag**
f_1	18.612620	0.348661	0.0081
f_2	18.807620	0.416727	0.0045
f_3	18.706380	0.779225	0.0038

Figure 1 presents the amplitude spectrum of TYC 2414-127-1 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.

The phased light curve of TYC 2414-127-1 with the following light elements:

$$\text{Max HJD(TT)} = 2459937.367 + 0^{\rm d}.053727 \times E$$

in the V and R_c filters is presented in Fig. 3.

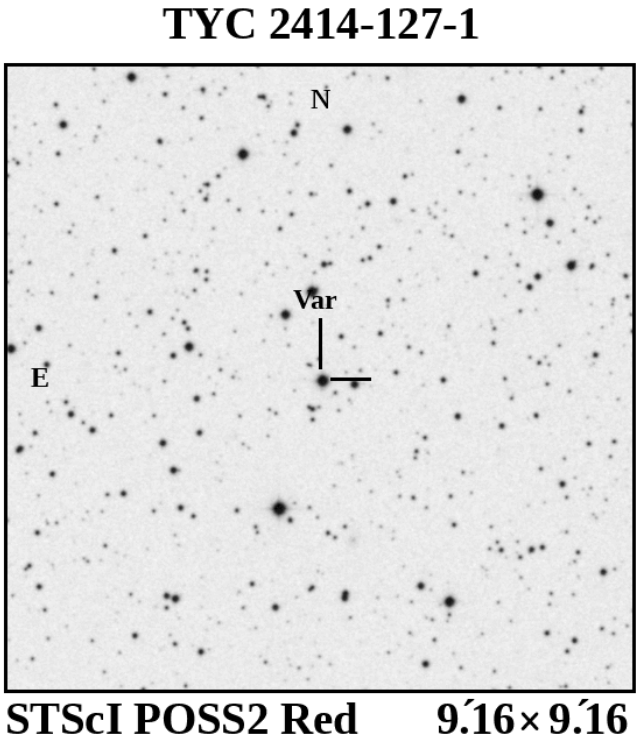

Figure 2. A finding chart for TYC 2414-127-1.

3.2 USNO-A2.0 1200-04164745

Both observing sets reveal rapid variations at a time scale of about $0^{\rm d}.08$ and with a peak-to-peak amplitude about $0^{\rm m}.1$. In Gaia DR3, Part 4, Variability by Gaia Collaboration (2022), the variability type specified for this star is RS, but this object is not present in the X-Ray 1RXS catalogue, see Voges at al. (1999). Based on our photometry, we assume the DSCT type of variability. To search for periodic signals in our observations, we use the Period04 software in the frequency range between 3 and 20 cycles per day, selected following recommendations by Breger (2000). Two apparently significant frequencies were detected; their parameters corresponding to Equation 3, determined by least squares, are collected in Table 5.

Table 5. Detected frequencies of USNO-A2.0 1200-04164745

	Frequency, c/d	**Φ**	**Amplitude, mag**
f_1	12.50865	0.655434	0.0180
f_2	11.92780	0.015228	0.0087

Figure 4 presents the amplitude spectrum of USNO-A2.0 1200-04164745 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 Figure 5. The phased light curve of USNO-A2.0 1200-04164745 with the following light elements:

$$\text{Max HJD(TT)} = 2459899.4356 + 0^{\rm d}.0799447 \times E$$

in the V and R_c filters is presented in Fig. 6.

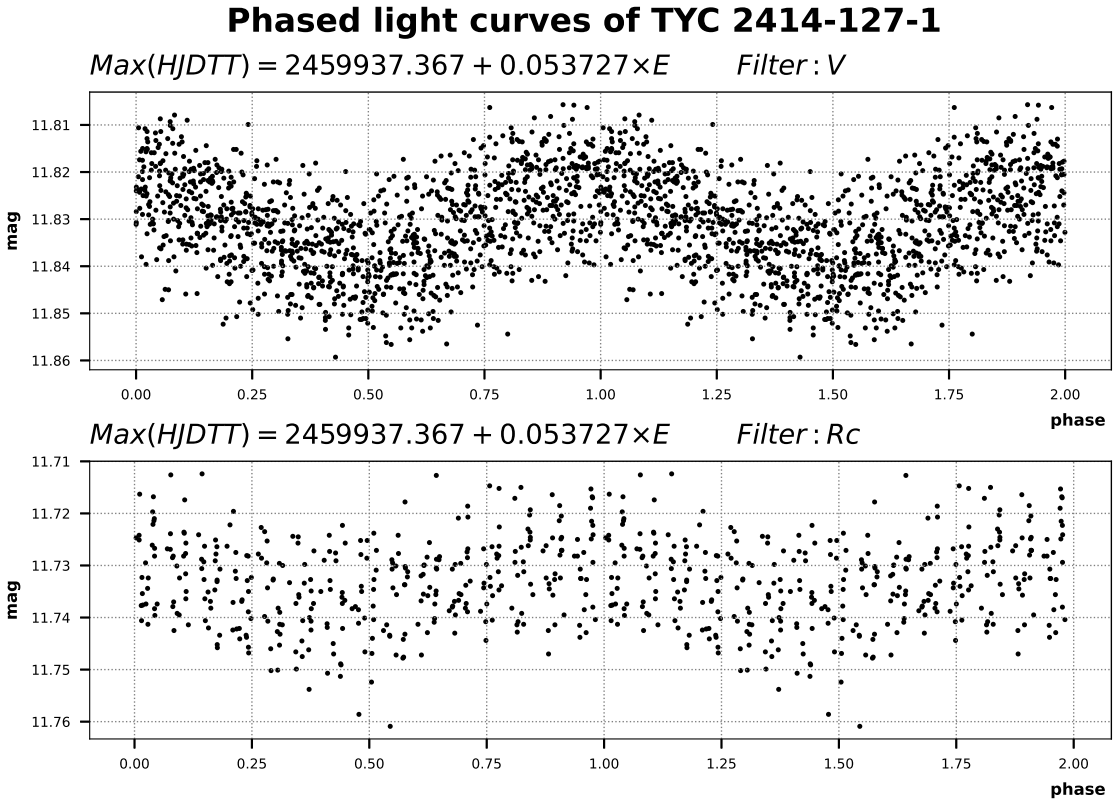

Figure 3. Phased light curves of TYC 2414-127-1.

4 Conclusions

I have found two small-amplitude δ Scuti (DSCT) variables in a field in Auriga, earlier studied by Kryachko et al. (2011). The first of them, TYC 2414-127-1, turns out to be multiperiodic, with three detected frequencies. For the second one, USNO-A2.0 1200-04164745, I found two frequencies. Finding charts and light curves are presented for both stars.

Acknowledgements: I would like to thank N.N. Samus for helpful discussion.

References:

Breger, M., 2000, *ASP Conference Series*, **210**, 3
ESA, 1997, The Hipparcos and Tycho Catalogues, ESA SP-1200, Vol. 1 (ESA97)
Gaia Collaboration, Vallenari, A., Brown, A. G. A., et al., 2022, ArXiv:2208.00211
Kryachko, T., Samokhvalov, A., Satovskiy, B., *Peremennye Zvezdy Prilozhenie (Variable Stars Supplement)*, 2011, **11**, No. 4
Lenz, P., Breger, M., 2005, *Comm. in Asteroseismology*, **146**, 53
Shatsky, N., Belinski, A., Dodin, A., et al. 2020, in *Ground-Based Astronomy in Russia. 21st Century*, ed. I. I. Romanyuk, I. A. Yakunin, A. F. Valeev, & D. O. Kudryavtsev, pp. 127–132
Sokolovsky, K. V., Lebedev, A. A., 2018, *Astron. and Computing*, **22**, 28
Voges, W., Aschenbach, B., Boller, Th., et al. 1999, *Astron. & Astrophys.*, **349**, 389

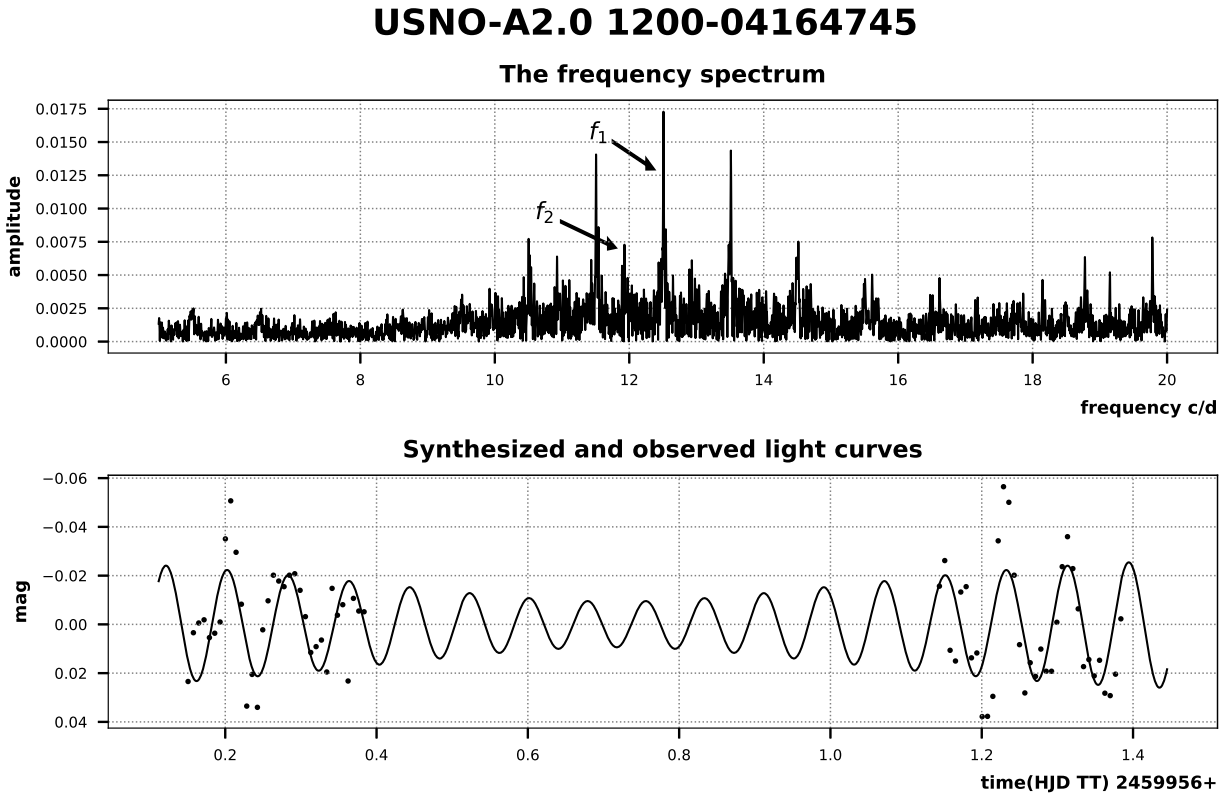

Figure 4. Frequency spectrum and light curve of USNO-A2.0 1200-04164745. In the bottom panel, the solid curve is the synthesized light curve and dots are observed data points.

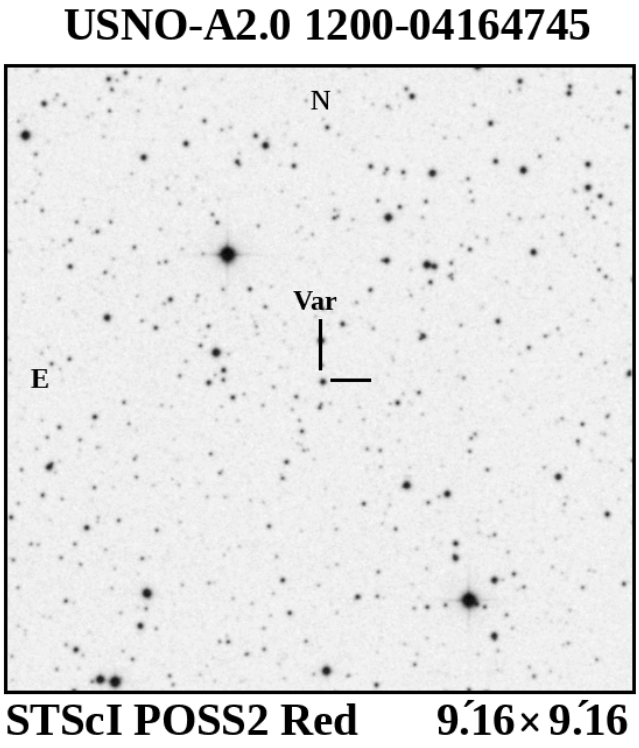

Figure 5. A finding chart for USNO-A2.0 1200-04164745.

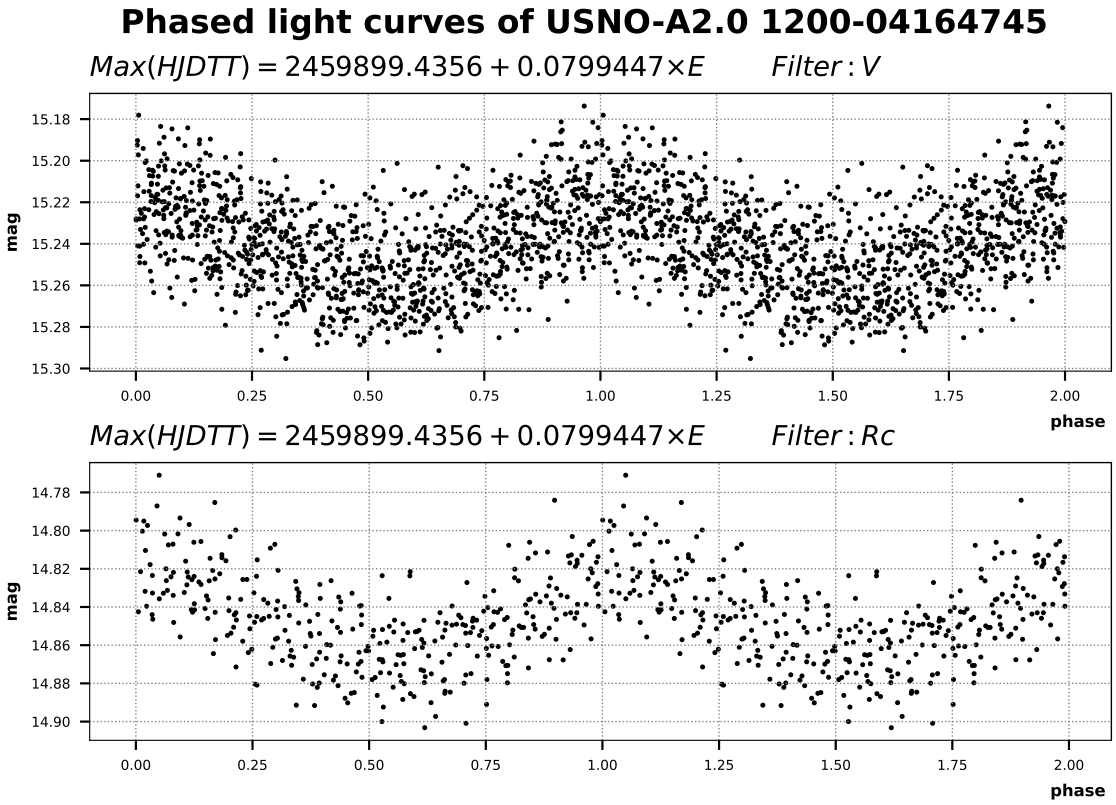

Figure 6. Phased light curves of USNO-A2.0 1200-04164745.