New Variables Discovered by Data Mining Images Taken During Recent Asteroid Photometric Surveys at the Astronomical Observatory of the University of Siena: Results for the Year 2017

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Abstract This paper continues the publication of the list of the new variables discovered at Astronomical Observatory, DSFTA, University of Siena, while observing asteroids for determining their rotational periods. Further observations of these new variables are strongly encouraged in order to better characterize these stars, especially those showing non-ordinary light curves.

1. Introduction

The most essential activity at the Astronomical Observatory of the University of Siena, within the facilities of the Department of Physical Sciences, Earth, and Environment (DSFTA 2018), is mentoring the students in astronomy lab activities. Every month students attend CCD observing sessions with of the purpose of getting time-series photometry of asteroids, exoplanets, and variables. The large number of CCD images collected this way also enabled us to plot light curves of all the variable stars detectable in the images and check for new variables. If any was found, the variable was added to the AAVSO International Variable Star Index (VSX; Watson *et al.* 2014), to share them with the larger community of professional and amateur astronomers.

2. Instrumentation and methods

All the variables were discovered in the images taken at the Astronomical Observatory of the University of Siena using a Clear filter that transmits all wavelengths from UV to IR, since the main goal of the observations was the photometric study of faint asteroids to determine their synodic rotational period. As discussed in our previous paper (Papini *et al.* 2015), where the reader can find a detailed description of the strategy which characterizes our observations, once a new variable was found, aperture photometry was performed on each subset of data. Magnitudes are given as CV, which designates observations made without filter or using a Clear filter, but using V magnitudes for the comparison stars from available catalogues. In such a way the result will be closer to V but will vary depending on the sensitivity of the observer's setup and the color of the comparison stars.

For this reason, we merged our data with those available on-line from the main surveys. The most useful surveys turned out to be ASAS-3 (All Sky Automated Survey; Pojmański 2002), CRTS (Catalina Real-Time Transient Survey; Drake 2014), and NSVS (Northern Sky Variability Survey; Wozniak 2004). A special mention is made of the GAIA survey (Gaia Collaboration *et al.* 2016), whose Data Release 2 (Gaia Collaboration *et al.* 2018; Lindegren *et al.* 2018) arrived while this article was being prepared. GAIA DR2 has permitted including more information about the new variable stars presented in this work, such as their distances, as reported in Table 2.

Since photometric filters used in these surveys were different, it was mandatory to set a constant zero-point to fit

Table 1. Observers and main features of the instruments used.

Observer	*Telescope**	*CCD*
Agnetti	28cm SCT f/10	Sbig ST-10
Arena	20cm NEW f/5	Atik 314L+
Bachini, Succi (A29)	40cm NEW f/5	DTA Discovery+ 260
Banfi (A25)	25cm SCT f/5	Sbig ST-7
Banfi (A36)	50cm NEW f/5	Sbig ST-9
Marchini (K54)	30cm MCT f/5.6	Sbig STL-6303E

** MCT = Maksutov-Cassegrain, NEW = Newton, SCT = Schmidt-Cassegrain*

all the available data. The main elements presented in this work are independent of absolute magnitude, and therefore we decided to shift our data vertically, adding the difference between the average of the survey magnitudes and the average of the differential magnitudes worked out from our images. However, when the light curve phased against the period was not complete, we asked members of the Variable Star Section of the Unione Astrofili Italiani (SSV-UAI 2018) to follow up on the variables and collect data for the "missing" part of the light curve. Given the faint magnitude of the variable, we accepted unfiltered observations and shifted as described above. Each observer performed his own photometric analysis using the same reference stars (generally 3–4). Table 1 lists the observers' names and the main features of their instruments.

3. Recent discovery list and results

In the accompanying list (Table 2), we present the 24 new variables discovered during 2017, which, added to the previously discussed variables in our papers (Papini *et al.* 2015, 2017), bring the total to 95 variables discovered since 2015. For the statistics, of the 24 variables, 16 are eclipsing binaries (one of EA type, 11 EW, 4 EB) and 8 are short period pulsators (one of RRab type, 4 DSCT, 3 HADS).

In the following sections, we discuss briefly the only star with peculiar behavior, and present the light curves of the most representative type of variables.

3.1. UCAC4 557-036373

UCAC4 557-036373 is an EW binary system with a period of about 0.39344 day that has a low amplitude light curve variation between magnitude 15.43 and 15.69 CV. It shows clearly the O'Connell effect (O'Connell 1951; Liu and Yang 2003) with the two maxima at different amplitudes. Data from surveys were not available for this star. Figure 1 shows the light curve phased with the main period of the binary.

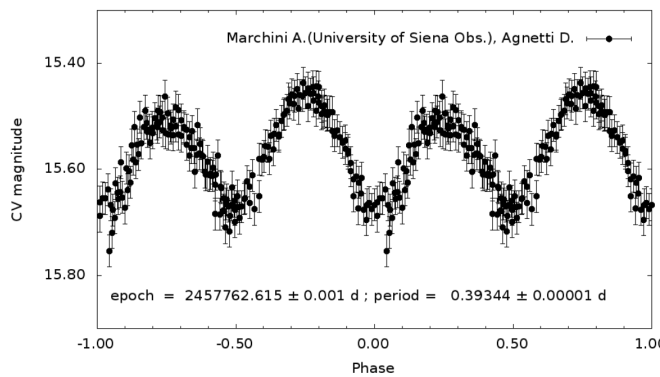

Figure 1. Folded light curve of UCAC4 557-036373.

Table 2. Main information and results for the new variables discovered.

Star (VSX identifier)	*R.A. (J2000)* h m s	*Dec. (J2000)* ° ′ ″	*Const.*	*Parallax* (*mas*)	*CV Mag*	*Period* (*days*)	*Epoch* (*HJD–2450000*)	*Type*
UCAC4 555-035787	06 59 09.13	+20 56 51.2	Gem	0.6879 ± 0.0698	15.16–15.70	0.38623 ± 0.00004	7762.6100 ± 0.0002	EW
UCAC4 557-036373	07 01 12.92	+21 17 32.7	Gem	0.4059 ± 0.0633	15.43–15.69	0.39344 ± 0.00001	7762.6150 ± 0.0008	EW
UCAC4 555-036219	07 01 38.40	+20 48 25.0	Gem	0.7917 ± 0.1300	15.97–16.30	0.37451 ± 0.00003	7760.6260 ± 0.0003	EW
GSC 01356-00372	07 02 31.80	+20 48 30.8	Gem	0.5267 ± 0.0392	13.41–13.51	0.081182 ± 0.000004	7759.3714 ± 0.0002	DSCT
GSC 01957-00131	09 17 33.89	+27 41 53.6	Cnc	0.0784 ± 0.0987	13.86–14.09	0.5060 ± 0.0001	7799.3868 ± 0.0002	EB
GSC 05536-00897	13 05 19.16	–09 09 18.9	Vir	0.5310 ± 0.0393	13.92–13.98	0.04562 ± 0.00006	7861.4271 ± 0.0004	DSCT
CMC15 J145002.3-051256	14 50 02.40	–05 12 56.0	Lib	0.4993 ± 0.0833	16.35–16.82	0.366271 ± 0.000004	7865.5445 ± 0.0003	EB
UCAC4 441-061555	15 50 44.36	–01 56 22.5	Ser		15.27–15.58	0.234492 ± 0.000002	7873.5057 ± 0.0004	EW
GSC 05627-00080	16 28 56.49	–08 07 27.1	Oph	0.4737 ± 0.3780	13.60–13.98	0.315999 ± 0.000005	7895.4496 ± 0.0003	EW
GSC 05627-00248	16 29 48.01	–07 45 11.4	Oph	0.5621 ± 0.0315	13.85–14.15	0.525977 ± 0.000004	7912.4069 ± 0.0003	EB
CMC15 J163041.4-080658	16 30 41.49	–08 06 58.9	Oph	0.0573 ± 0.1123	16.22–16.78	0.062443 ± 0.000004	7895.4461 ± 0.0005	HADS
UCAC4 410-066217	16 32 23.19	–08 01 43.3	Oph	1.1583 ± 0.0545	15.03–15.47	0.315450 ± 0.000004	7900.4089 ± 0.0003	EW
UCAC4 460-061118	16 51 31.20	+01 53 25.7	Oph	0.1344 ± 0.0834	16.25–16.60	0.066938 ± 0.000001	7899.5595 ± 0.0004	HADS
CMC15 J172111.9-045046	17 21 11.95	–04 50 46.1	Oph	0.1530 ± 0.1083	15.97–16.45	0.111612 ± 0.000001	7889.4210 ± 0.0004	HADS
UCAC4 428-070068	17 22 31.18	–04 32 53.5	Oph	0.2994 ± 0.0565	14.43–14.74	0.624796 ± 0.000005	7891.5091 ± 0.0004	RRAB
CMC15 J172246.1-043401	17 22 46.20	–04 34 01.1	Oph	0.8155 ± 0.1243	15.83–16.45	0.315587 ± 0.000006	7889.5333 ± 0.0004	EW
UCAC4 370-097050	17 38 28.90	–16 09 01.8	Oph	1.3581 ± 0.0369	14.30–14.80	0.358423 ± 0.000003	7924.4495 ± 0.0002	EW
UCAC4 369-097914	17 39 11.15	–16 16 25.2	Oph	0.7032 ± 0.0263	13.60–14.17	0.870247 ± 0.000006	7922.4514 ± 0.0005	EB
GSC 05117-01301	18 39 47.51	–02 45 05.8	Ser	2.4761 ± 0.0249	13.85–14.55	0.547939 ± 0.000002	7935.3423 ± 0.0001	EA
GSC 05117-00326	18 40 45.36	–02 26 19.5	Ser	0.4171 ± 0.0251	14.41–14.52	0.119096 ± 0.000004	7930.4890 ± 0.0003	DSCT
UCAC4 641-065317	19 06 44.58	+38 10 12.9	Lyr	0.6471 ± 0.0184	13.92–14.61	0.503517 ± 0.000003	7906.5021 ± 0.0002	EW
CMC15 J190719.6+375515	19 07 19.60	+37 55 15.5	Lyr	0.5615 ± 0.0451	16.37–16.92	0.285236 ± 0.000003	7907.4353 ± 0.0002	EW
UCAC4 641-065553	19 08 00.32	+38 01 57.1	Lyr	0.3778 ± 0.0343	15.69–16.24	0.398495 ± 0.000004	7907.5396 ± 0.0003	EW
UCAC4 409-132318	20 38 50.28	–08 22 42.1	Aqr	0.2866 ± 0.0420	15.09–15.20	0.058415 ± 0.000004	7951.4911 ± 0.0003	DSCT

Note: The column "Parallax" is derived from Gaia Data Release 2 data, recently available, and the value is expressed in milli-arcseconds. The column CV Mag is the magnitude range expressed in Clear (unfiltered) band aligned at V band, as explained in Section 2.

3.2. Eclipsing binaries

Since there are no stars in this class that show peculiar features or behavior, we will discuss in this section a few typical stars for each main subtype. GSC 05117-01301 is an eclipsing binary of EA type with a period of about 0.547939 day and a large amplitude light curve variation between magnitude 13.85 and 14.55 CV. Minima are quite similar in depth. No survey data were available for this star. Figure 2 shows the light curve phased with the main period of the binary.

GSC 05627-000248 is an eclipsing binary of EB type with a period of about 0.525977 day and an amplitude light curve variation between magnitude 13.85 and 14.15 CV. Minima are quite different in depth. Survey data from CRTS were available for this star and were added to our data. Figure 3 shows the light curve phased with the main period of the binary.

UCAC4 370-097050 is an eclipsing binary of EW type with a period of about 0.358423 day and a large amplitude light curve variation between magnitude 14.30 and 14.80 CV. Minima are slightly different in depth. No survey data were available for this star. Figure 4 shows the light curve phased with the main period of the binary.

3.3. Short period pulsators

As with the eclipsing binaries, there are no stars in this class that show peculiar features or behavior, and therefore we will discuss in this section a few typical stars for each main subtype. GSC 05536-00897 is a DSCT pulsating star with a very short pulsation period of about 0.04562 day (1 hour and 5 minutes!) and a very small amplitude of the light curve variation between magnitude 13.92 and 13.98 CV. Data from CRTS survey were available for this star and added to our data. The resulting light curve is quite symmetric and there is no evidence of amplitude and/or period variation, at least compared to the old data from CRTS survey. Figure 5 shows the light curve phased with the main period of the pulsator.

CMC15 J163041.4-080658 is a DSCT pulsating star with a very short pulsation period of about 0.062443 day (1 hour and 29 minutes) and a large amplitude of the light curve variation between magnitude 16.22 and 16.78 CV. Data from CRTS survey were available for this star and were added to our data. The resulting light curve shows a rapid ascending branch and there is no evidence of amplitude and/or period variation, at least compared to the old data from CRTS survey. Figure 6 shows the light curve phased with the main period of the pulsator.

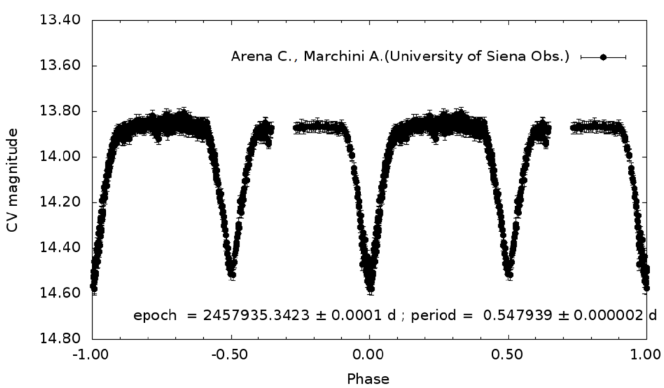

Figure 2. Folded light curve of GSC 05117-01301.

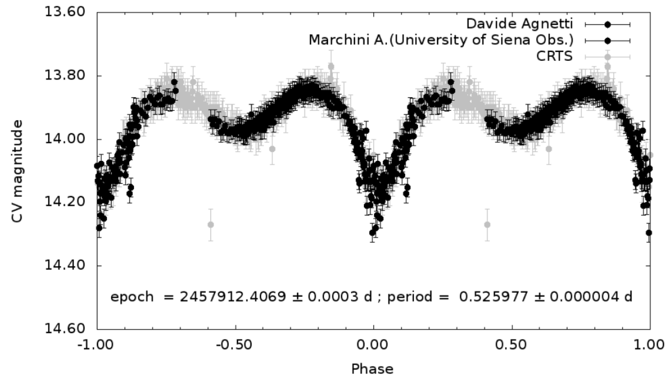

Figure 3. Folded light curve of GSC 05627-00248.

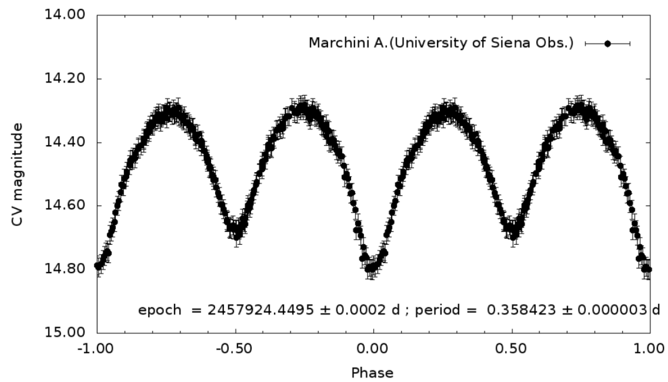

Figure 4. Folded light curve of UCAC4 370-097050.

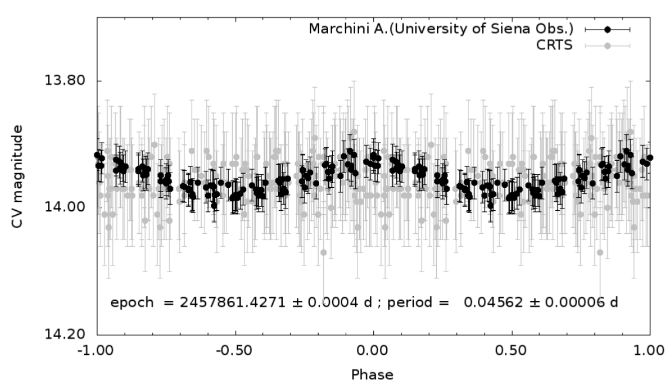

Figure 5. Folded light curve of GSC 05536-00897.

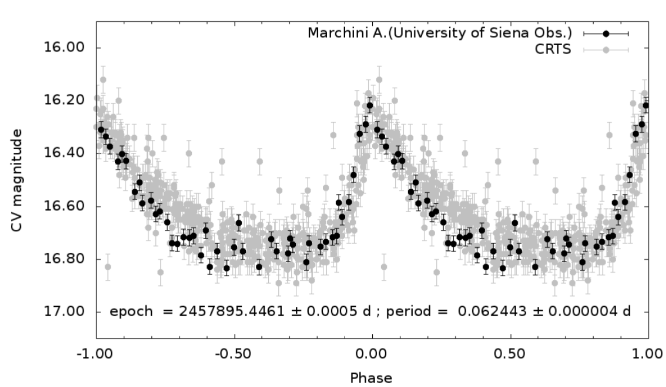

Figure 6. Folded light curve of CMC15 J163041.4-080658.

4. Conclusions

Mentoring the students in astronomy lab activities using a telescope with a CCD camera at the Astronomical Observatory of the University of Siena allowed us to collect a large amount of CCD images and dig inside this mine to search for new variables. Variables discovered this way are added to the AAVSO International Variable Star Index (VSX), to share them with the larger community of professional and amateur astronomers. In 2017 we discovered 24 new variable stars, specifically, 16 eclipsing binaries and 8 short period pulsators. The details of each of the new variable stars are given in Table 2 in order of increasing Right Ascension. Phase plots are shown in Figures 1 through 6 in section 3.

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