New Variable Stars Discovered by Data Mining Images Taken during Recent Asteroid Photometric Observations. II. Results from July 2015 through December 2016

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Abstract This paper follows the previous publication of new variables discovered at Astronomical Observatory, DSFTA, University of Siena, while observing asteroids in order to determine their rotational periods. Usually, this task requires time series images acquisition on a single field for as long as possible on a few nights not necessarily consecutive. Checking continually this "goldmine" allowed us to discover 57 variable stars not yet listed in catalogues or databases. While most of the new variables are eclipsing binaries, a few belong to the RR Lyrae or delta Scuti class. Since asteroid work is definitely a time-consuming activity, coordinated campaigns of follow-up with other observatories have been fundamental in order to determine the elements of the ephemeris and sometimes the right subclass of variability. Further observations of these new variables are therefore strongly encouraged in order to better characterize these stars, especially pulsating ones whose data combined with those taken during professional surveys seem to suggest the presence of light curve amplitude and period variations.

1. Introduction

In this paper, we present the results of the new variables discovered while taking CCD images for other purposes from July 2015 through December 2016 at the Astronomical Observatory of the University of Siena, inside the facilities of the Department of Physical Sciences, Earth, and Environment (DSFTA 2017). In fact, one of the many activities of the observatory, besides student mentoring in astronomy, is taking CCD images of asteroids for plotting their light curves in order to work out their synodic rotational period, and therefore plenty of images are available for checking for new variable stars (Papini *et al.* 2015). During that period, thanks to the remote control capabilities of the observatory, our group discovered 57 new variables—specifically, 46 eclipsing binaries and 11 short period pulsators—which include the 14 discovered in first half of 2015. In the end, new variable stars have been added to VSX (Variable Star Index) operated by the AAVSO, for sharing them with the larger community of professionals and amateurs (Watson *et al.* 2014).

2. Instrumentation and methods

We refer the reader to our previous paper (Papini *et al.* 2015) for a detailed description of the observation strategy, hardware and software systems, which characterized our observations that did not undergo any relevant change during the second season apart from new observers and therefore telescopes involved. Table 1 lists the main features of the instruments. Actually, all the variables were discovered in the images taken at the Astronomical Observatory of the University of Siena. For roughly half of these, the number of images was large enough for a complete characterization, but for the other half a follow-up involving other observers and telescopes was necessary to let the main scope at Siena keep on following asteroids and other institutional projects. Most of the authors that helped in the follow-up are members of the Variable Star Section of the Unione Astrofili Italiani (SSV-UAI 2017).

3. Results

In Table 2 we summarize the main parameters for the 57 new variables. Each of them can easily be looked for in the AAVSO VSX database through its identifier, as it appears in the first column. In the table, Epoch means time of maximum brightness for pulsating stars and time of primary minimum for eclipsing binaries.

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

Observer	*Telescope**	*CCD*
Agnetti	11" SCT f/10	Sbig ST-10
Bacci (104)	23" NEW f/4.3	Apogee U7
Banfi (A25)	10" SCT f/5	Sbig ST-7
Banfi (A36)	20" NEW f/5	Sbig ST-9
Bianciardi	6" NEW f/5	Sbig ST-8XME
Collina	8" SCT f/10	QHYCCD QHY163M
Galli (B14)	9.25" SCT f/6.3	Sbig ST-8XME
Ghiri, Milani	8" RC f/4.6	ATIK One 6.0
Lopresti	7" MNT f/4	Sbig ST-10XME
Marchini (K54)	12" MCT f/5.6	Sbig STL-6303E
Marino	10" NEW f/4.8	Sbig ST-7XME
Rizzuti	8" SCT f/7	Sbig ST-7
Ruocco (C82)	10" SCT f/10	Sbig ST-7
Quadri (565)	12" SCH f/3.1	Starlight Trius SX9

* *Telescope types: MCT—Maksutov-Cassegrain, MNT—Maksutov-Newton, NEW—Newton, RC—Ritchey–Chrétien, SCH—Schmidt, SCT—Schmidt-Cassegrain.*

Over 80% of the new variables are eclipsing binaries: 33 of them are EW type, 10 are EA type and 3 are EB type. The other 20% are mainly pulsating stars: 3 of them are HADS, 3 are RRc, 2 are DSCT, one is EC+BY, one is RRab/BL, and one is RRc/BL. Some of them show interesting peculiarities in their light curves, and are presented below.

3.1. GSC 00563-00194

GSC 00563-00194 shows very low amplitude periodic light curve variations. The frequency analysis has revealed a strong peak at about 2.91 cycles/day and a few weaker peaks. With the support of the VSX moderator, Sebastian Otero, we concluded that fast variation was not likely a real pulsation but the result of two red stars, one perhaps a BY Dra, rotating quickly around the common center of mass. The magnitude varies from 13.42 to 13.65 CV. In Figure 1, the light curve is phased with the period of the strongest peak of the power spectrum. Further observing of this star should be encouraged in order to refine the knowledge of this peculiar system.

3.2. GSC 00153-00900

GSC 00153-00900 is an eclipsing binary with a period of 0.330478 day that has a very low amplitude light curve variation between magnitudes 13.49 and 13.62 CV. It shows clearly the O'Connell effect (O'Connell 1951; Liu and Yang 2003) where the two out-of-eclipse maxima are of different brightnesses. No survey data were available for this star. In Figure 2, the light curve is phased with the main period of the binary.

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

Star (VSX identifier)	*R.A. (J2000)* h m s	*Dec. (J2000)* ° ′ ″	*Const.*	*V*	*Period* (days)	*Epoch* (HJD-2450000)	*Type*
UCAC4 458-000015	00 00 43.40	+01 34 07.7	Psc	15.38–15.66	0.292532 ± 0.000002	7641.6336 ± 0.0001	EW
2MASS J00211826+4233308	00 21 18.26	+42 33 30.8	And	16.30–16.71	0.235728 ± 0.000003	7248.5553 ± 0.0001	EW
GSC 01826-00950	04 06 29.72	+29 46 10.7	Tau	13.72–13.98	3.104790 ± 0.000003	7366.3030 ± 0.0002	EA
GSC 01274-01261	04 37 06.22	+19 37 06.1	Tau	13.65–14.08	0.350189 ± 0.000002	7377.5471 ± 0.0002	EW
GSC 01849-01030	05 06 18.62	+24 44 48.4	Tau	14.41–14.87	0.528494 ± 0.000003	7729.4341 ± 0.0002	EW
UCAC4 574-014734	05 13 23.13	+24 47 27.5	Tau	15.27–15.63	0.401251 ± 0.000003	7730.5028 ± 0.0002	EW
CMC15 J051332.5+245225	05 13 32.51	+24 52 25.7	Tau	16.44–17.19	0.263871 ± 0.000003	7723.3653 ± 0.0002	EW
UCAC4 575-015133	05 13 33.05	+24 53 47.3	Tau	15.45–15.57	0.079055 ± 0.000003	7730.3316 ± 0.0002	DSCT
UCAC4 575-015216	05 14 03.89	+24 57 07.4	Tau	15.64–15.85	0.510915 ± 0.000003	7730.4856 ± 0.0002	EW
UCAC4 574-014986	05 14 54.57	+24 36 10.0	Tau	14.35–15.28	0.305952 ± 0.000003	7722.3963 ± 0.0002	EW
UCAC4 574-015078	05 15 40.84	+24 44 16.6	Tau	15.58–15.87	0.469001 ± 0.000003	7730.4662 ± 0.0002	EW
UCAC4 576-015082	05 17 36.38	+25 01 50.4	Tau	15.25–16.05	0.330558 ± 0.000003	7721.6502 ± 0.0002	EW
UCAC4 593-021345	05 42 28.61	+28 24 52.4	Tau	15.13–15.50	1.072244 ± 0.000005	7387.4874 ± 0.0003	EA
UCAC4 593-021583	05 44 07.39	+28 31 40.8	Tau	15.77–16.55	1.275370 ± 0.000004	7384.3341 ± 0.0003	EW
UCAC4 617-029871	05 55 14.35	+33 17 15.4	Aur	16.35–16.73	0.584840 ± 0.000003	7750.5405 ± 0.0002	EW
UCAC4 617-029939	05 55 29.30	+33 20 24.2	Aur	16.18–16.33	0.342309 ± 0.000003	7744.4945 ± 0.0002	EW
CMC15 J055640.5+331906	05 56 40.56	+33 19 07.0	Aur	16.40–16.80	0.487440 ± 0.000003	7751.4689 ± 0.0002	EW
UCAC4 617-030583	05 58 19.23	+33 17 15.5	Aur	15.41–15.83	0.464030 ± 0.000003	7744.5700 ± 0.0002	EW
UCAC4 623-031110	06 09 03.11	+34 31 25.5	Aur	15.13–15.42	0.395718 ± 0.000003	7738.4823 ± 0.0002	EW
GSC 02428-00994	06 10 43.14	+34 38 50.1	Aur	13.20–13.69	0.854036 ± 0.000003	7731.6384 ± 0.0002	EA
UCAC4 625-030777	06 11 13.37	+34 49 15.1	Aur	16.78–17.19	0.534203 ± 0.000003	7740.6175 ± 0.0002	EW
UCAC4 625-030811	06 11 25.00	+34 49 22.0	Aur	15.92–16.25	0.272109 ± 0.000003	7738.4233 ± 0.0002	EW
UCAC4 549-029087	06 32 51.16	+19 40 26.8	Gem	16.12–16.46	0.35234 ± 0.00003	7746.5757 ± 0.0002	EW
GSC 00153-00641	06 57 57.90	+02 44 55.1	Mon	13.88–14.18	0.845821 ± 0.000003	7440.28477 ± 0.00003	EA
UCAC4 464-024612	06 58 33.84	+02 46 10.5	Mon	15.09–15.27	0.300049 ± 0.000003	7424.41937 ± 0.00002	EW
GSC 00153-00900	06 58 37.32	+02 39 53.1	Mon	13.49–13.62	0.330478 ± 0.000004	7424.27473 ± 0.00002	EW
GSC 01357-00941	07 06 09.29	+21 23 08.8	Gem	13.78–14.88	0.606386 ± 0.000005	7858.4307 ± 0.0003	EB
GSC 01357-00131	07 07 28.08	+20 54 40.5	Gem	12.60–12.83	0.372912 ± 0.000003	7752.41947 ± 0.00003	EW
UCAC4 555-037258	07 07 39.59	+20 57 04.2	Gem	15.03–15.25	0.30430 ± 0.00003	7753.3270 ± 0.0002	EW
GSC 01357-00639	07 08 50.00	+21 10 29.2	Gem	14.01–15.01	0.51556 ± 0.00003	7754.5389 ± 0.0002	EB
UCAC4 555-037760	07 10 53.56	+20 52 24.1	Gem	16.18–16.71	0.37237 ± 0.00003	7753.4253 ± 0.0002	EW
GSC 00777-00241	07 32 48.17	+14 31 11.8	Gem	14.09–14.84	0.659291 ± 0.000005	7409.6781 ± 0.0003	EA
GSC 00777-00233	07 33 57.85	+14 34 46.2	Gem	13.44–13.88	0.322852 ± 0.000003	7373.6834 ± 0.0002	RRc
GSC 00913-01147	14 31 19.78	+10 00 42.7	Boo	13.68–13.83	0.303115 ± 0.000003	7489.43435 ± 0.00003	EW
UCAC4 424-061076	14 58 05.48	–05 17 22.1	Lib	14.90–15.60	0.290211 ± 0.000003	7495.45966 ± 0.00002	EW
UCAC4 501-063071	16 03 24.62	+10 05 09.0	Ser	14.93–15.15	0.347757 ± 0.000003	7515.6348 ± 0.0002	EW
UCAC4 374-078489	16 57 05.54	–15 19 29.0	Oph	16.03–16.75	0.858035 ± 0.000003	7545.4693 ± 0.0001	EA
UCAC4 373-080823	16 58 40.03	–15 33 07.7	Oph	16.66–17.40	0.307275 ± 0.000001	7545.5041 ± 0.0001	EW
UCAC4 373-080978	16 59 41.41	–15 32 34.3	Oph	14.45–15.56	0.447718 ± 0.000003	7564.5318 ± 0.0001	RRab/BL
UCAC4 371-080964	17 06 11.75	–15 59 34.3	Oph	15.09–15.78	0.331897 ± 0.000001	7538.552 ± 0.002	EW
UCAC4 373-082585	17 08 29.46	–15 35 43.1	Oph	15.53–16.01	0.077260 ± 0.000003	7536.4818 ± 0.0001	HADS
UCAC4 372-080369	17 09 02.69	–15 44 44.5	Oph	14.24–14.77	0.296369 ± 0.000003	7591.4285 ± 0.0001	RRc
UCAC4 372-080463	17 09 26.20	–15 40 53.9	Oph	15.39–15.85	0.263596 ± 0.000003	7536.4684 ± 0.0001	RRc
UCAC4 373-083099	17 10 29.47	–15 33 08.9	Oph	15.46–15.95	0.072193 ± 0.000003	7539.3864 ± 0.0001	HADS
GSC 05747-01746	20 08 13.41	–12 48 31.6	Cap	13.23–13.49	1.989495 ± 0.000003	7227.4105 ± 0.0004	EA
GSC 04263-01334	22 06 08.81	+60 12 04.1	Cep	12.03–12.34	0.553207 ± 0.000002	7615.6304 ± 0.0001	EB
UCAC4 753-074179	22 07 51.61	+60 29 09.6	Cep	12.71–12.94	0.697644 ± 0.000016	7643.5687 ± 0.0001	EW
2MASS J22080014+6026144	22 08 00.14	+60 26 14.5	Cep	17.40–17.90	0.594572 ± 0.000002	7615.5067 ± 0.0001	EW
GSC 05806-01614	22 09 17.60	–10 08 40.1	Aqr	14.74–14.84	0.041375 ± 0.000003	7654.4345 ± 0.0002	DSCT
UCAC4 751-072394	22 09 21.69	+60 06 48.4	Cep	15.45–15.72	0.439675 ± 0.000002	7615.5778 ± 0.0001	EW
UCAC4 751-072412	22 09 29.80	+60 03 26.4	Cep	14.18–14.54	1.273040 ± 0.000002	7615.5520 ± 0.0001	EA
UCAC4 751-072684	22 10 45.65	+60 04 23.2	Cep	15.50–15.94	4.291477 ± 0.000004	7615.5190 ± 0.0003	EA
2MASS J22111437+6002162	22 11 14.37	+60 02 16.3	Cep	16.41–16.83	0.546590 ± 0.000022	7635.5256 ± 0.0001	EW
UCAC4 700-108862	22 19 05.70	+49 53 26.6	Lac	14.45–14.78	0.70440 ± 0.00003	7233.3997 ± 0.0002	EA
GSC 00563-00194	22 28 19.26	+03 22 02.4	Peg	13.42–13.65	0.343580 ± 0.000005	7603.4517 ± 0.0003	EC+BY
UCAC4 442-129803	23 51 44.10	–01 46 28.0	Psc	15.34–15.89	0.392769 ± 0.000003	7657.5208 ± 0.0002	RRc/BL
GSC 00587-00276	23 55 14.60	+00 03 22.2	Psc	13.80–14.13	0.078703 ± 0.000002	7651.4269 ± 0.0001	HADS

3.3. GSC 00913-01147

GSC 00913-01147 is an eclipsing binary with a period of 0.303115 day that has a very low amplitude light curve variation of only 0.15 magnitude between 13.68 and 13.83 CV. It shows clearly the O'Connell effect. Data from CRTS survey were available for this star. In Figure 3, the light curve is phased with the main period of the binary.

3.4. UCAC4 373-080978

UCAC4 373-080978 is an RRab stars with a period of 0.447718 day and an amplitude of about 1.1 magnitude between 14.45 and 15.56 CV. It shows a slight amplitude light curve variation compared to the old data from the CRTS survey. This behavior is often associated with the Blazhko effect (Blazhko 1907). In Figure 4, the light curve is phased with the main period of the pulsator.

3.5. UCAC4 442-129803

UCAC4 442-129803 is an RRc star with a period of 0.392769 day and an amplitude of 0.55 magnitude between 15.34 and 15.89 CV. It shows clearly a phase light curve variation compared to the old data from CRTS survey. This behavior is often associated with the Blazhko effect. In Figure 5, the light curve is phased with the main period of the pulsator.

4. Conclusions

After having observed asteroids for about one year and half in order to determine their mean light curves and periods, we have collected thousands of images, many of which are centered for the entire night on the same field. Doing variable star search in these fields allowed us to discover 57 new variable stars, specifically, 46 eclipsing binaries and 11 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 for few peculiar stars are shown in Figures 1 through 5.

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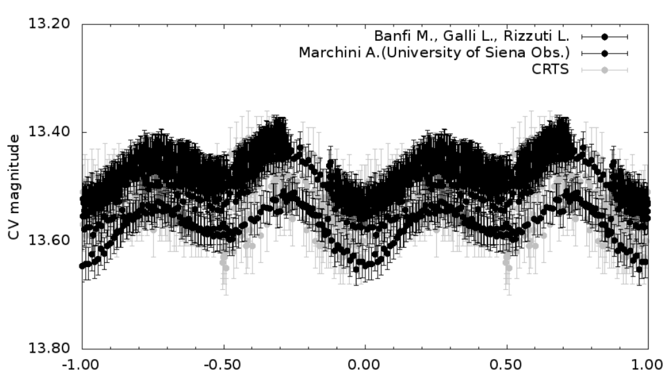

Figure 1. Folded light curve of GSC 00563-00194.

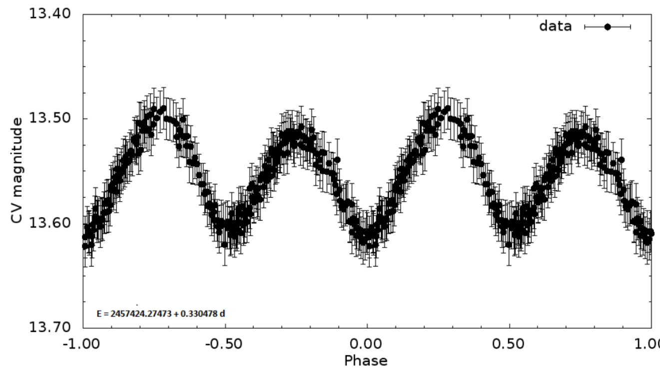

Figure 2. Folded light curve of GSC 00153-00900.

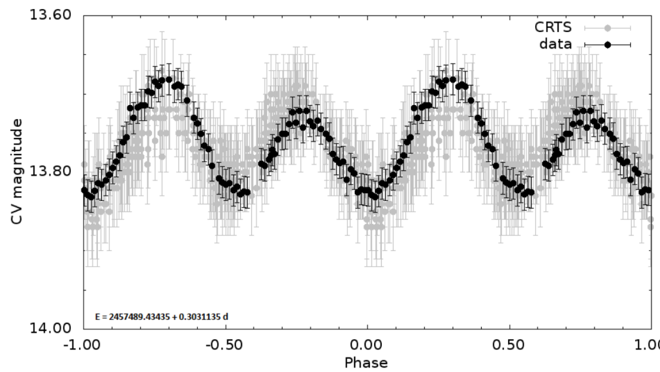

Figure 3. Folded light curve of GSC 00913-01147.

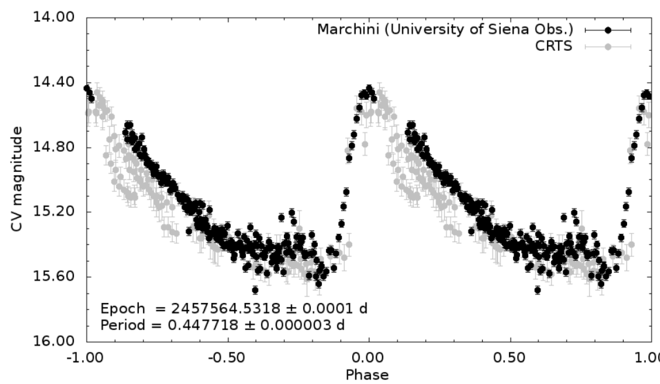

Figure 4. Folded light curve of UCAC4 373-080978.

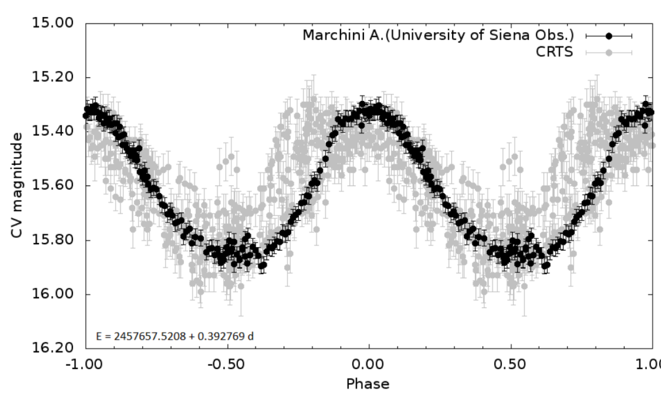

Figure 5. Folded light curve of UCAC4 442-129803.

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