NEW BINARY SYSTEMS WITH ASYMMETRIC LIGHT CURVES

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ABSTRACT. We present the results of investigation of the light curves of 27 newly discovered binary systems. Among the examined curves, there were 10 curves with statistically significant asymmetry of maximums, according the 3σ criterion for the difference between the maximal brightness. Half of these 10 curves have a higher first maximum, another half the second one. Two of these 10 curves, USNO-B1.0 1629-0064825 = VSX J052807.9+725606 and USNO-B1.0 1586-0116785, show the largest difference between magnitudes in maxima. The star VSX J052807.9+725606 also shows the secondary minimum, which is shifted from the phase $\varphi = 0.5$. The shape of the curve argues that the physical processes of this star could be close to that of well known short periodic binary system V361 Lyr, which has a spot on the surface of one star of the system. Another star, USNO-B1.0 1586-0116785, probably has a cold spot, or several spots, in the photosphere of one of the components.

Keywords: Variable stars: eclipsing, interacting binary, impactors

Introduction

Nowadays, using rather accurate CCD photometry, it is possible to detect fine features of the light curves. Weve noticed that among various shapes of the phase curves of close eclipsing binary systems the asymmetry shapes arent very unusual. Many authors points that there are binary systems with rather steady asymmetric curves, other noticed that the shape of the phase curve may change in different years. To make an investigation of this effect, we decided to determine the number of statistically significant asymmetric curves among those binary systems, which we discovered during 2009-2010. Weve examined all 27 phase curves of binary systems of different types, which were discovered and approved in this period. All observations were obtained using the remotely controlled telescopes of Tzec Maun observatory: -180 (D=180mm, F=1410mm) equipped with the CCD camera SBIG STL-11000, the field of view was 87.5'x58.3', and FSQ-106 (D=106mm, F=527mm) equipped with the same CCD camera, the field of view was 233.8'x155.9'.

Statistical modeling

For the examined 27 binary systems all parameters needed for the General Catalog of Variable Stars (GCVS) were determined using the FDCN software (Andronov, 1994, 2003). This program computes the coefficients of the statistically optimal smoothing trigonometric polynomials using the least squares method routine and differential corrections for the period, which allowed determine all photometric parameters with corresponding errors. Some of these stars we already registered in the VSX catalog Variable Stars IndeX, operated by AAVSO. The information about the USNO-B.1 numbers of the stars, their coordinates, VSX numbers and types are given in the Table 1.

The information about the periods, magnitudes of maxima and minima was summarized in the Table 2. According to the 3σ criterion, the values which are marked in bold type correspond to the stars with statistically asymmetric curves.

Statistically significant asymmetry

From the Table 1 weve noticed that among the examined 27 light curves, there were 10 curves with statistically significant asymmetry of maxima. This means that more than 1/3 of our binary systems has asymmetric phase curves. We introduced two parameters. The first is the difference between magnitudes in maxima: $\Delta\max = \mathrm{Max}_{\mathrm{II}}\text{-}\mathrm{Max}_{\mathrm{I}}$.

The second is the difference between the magnitudes in the primary minimum and in the secondary maximum: $A = \min_{\mathrm{I}}\text{-}\mathrm{Max}_{\mathrm{II}}$. Both these parameters are also given in the Table 2.

We looked for the different statistical dependences:
1. between $\Delta\max$ and $\Delta\max/A$. The corresponding diagram is shown on the Fig. 1;

Table 1. Identifications and co-ordinates (2000.0) of new variable stars

No	USNO-B1.0	RA	DEC	VSX	Type
1	USNO-B1.0 0746-0450359	$17^h44^m43^s.452$	-15°20'14.12"	VSX J174443.4-152014	Ell:
2	USNO-B1.0 0746-0452118	$17^h45^m09^s.615$	-15°23'29.54"	VSX J174509.6-152329	EW
3	USNO-B1.0 1624-0096365	$11^h37^m27^s.240$	+72°24'03.43"	VSX J113727.2+722403	EW
4	USNO-B1.0 1611-0091801	$11^h48^m36^s.524$	+71°07'51.14"	VSX J114836.5+710751	EW
5	USNO-B1.0 1630-0091892	$11^h55^m58^s.219$	+73°00'25.33"	VSX J115558.2+730025	EW
6	USNO-B1.0 1611-0091333	$11^h40^m30^s.022$	+71°11'02.44"	VSX J114030.0+711102	EW
7	USNO-B1.0 1615-0092898	$12^h06^m41^s.287$	+71°32'46.93"	VSX J120641.2+713246	EW
8	USNO-B1.0 1229-0276915	$14^h13^m40^s.556$	+32°56'48.16"	VSX J141340.5+325648	EW
9	USNO-B1.0 1238-0228470	$14^h15^m09^s.282$	+33°52'22.12"	VSX J141509.2+335222	EB
10	USNO-B1.0 1017-0168554	$08^h53^m48^s.933$	+11°43'53.64"	VSX J085348.9+114353	EW
11	USNO-B1.0 1015-0165372	$08^h54^m38^s.967$	+11°33'00.23"	VSX J085438.9+113300	EW
12	USNO-B1.0 1629-0064825	$05^h28^m07^s.975$	+72°56'06.05"	VSX J052807.9+725606	E
13	USNO-B1.0 1634-0053325	$05^h33^m00^s.072$	+73°27'26.52"		EW
14	USNO-B1.0 1633-0056300	$05^h28^m25^s.539$	+73°21'14.57"		EW
15	USNO-B1.0 1635-0051301	$05^h35^m14^s.565$	+73°31'24.19"		EW
16	USNO-B1.0 1628-0064829	$05^h30^m44^s.331$	+72°51'13.67"		EA
17	USNO-B1.0 1624-0065083	$05^h25^m43^s.672$	+72°28'40.10"		EA
18	USNO-B1.0 1636-0050887	$05^h34^m44^s.439$	+73°40'06.37"		Ell
19	USNO-B1.0 1167-0308859	$17^h39^m14^s.053$	+26°42'43.19"		EW
20	USNO-B1.0 1165-0287124	$17^h38^m22^s.563$	+26°33'04.40"		E
21	USNO-B1.0 1165-0287544	$17^h39^m14^s.265$	+26°32'02.09"		EW
22	USNO-B1.0 1160-0265767	$17^h37^m23^s.199$	+26°02'51.73"		EA
23	USNO-B1.0 1161-0280071	$17^h39^m52^s.694$	+26°10'20.02"		EW
24	USNO-B1.0 1159-0264420	$17^h38^m51^s.239$	+25°57'46.69"		EB
25	USNO-B1.0 1164-0290487	$17^h38^m59^s.968$	+26°28'28.94"		EW
26	USNO-B1.0 1165-0287332	$17^h38^m48^s.917$	+26°34'37.20"		EW
27	USNO-B1.0 1586-0116785	$11^h28^m25^s.293$	+68°37'17.46"		EB

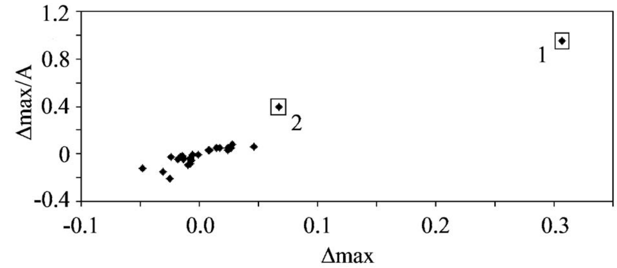

Fig.1. Diagram Δmax/A vs. Δmax.

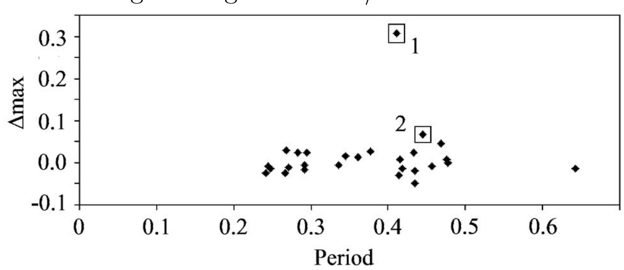

Fig.2. Diagram Δmax/A vs. period

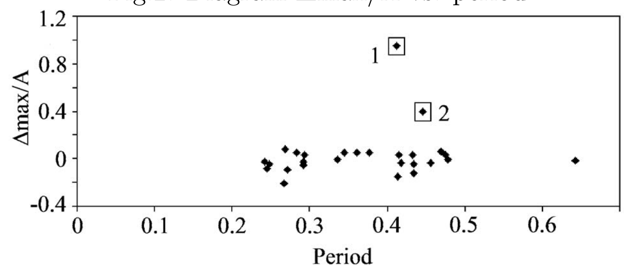

Fig.3. Diagram Δmax vs. period.

Table 2. Characteristics of new variable stars: number (as in Table 1), type, period P, initial epoch T_0, brightness at maxima and minima (photometric system "clear R"), difference between the maxima $\Delta\text{max} = \text{max}_{\text{II}} - \text{max}_{\text{I}}$ and its ratio to the corresponding error estimate σ and amplitude A defined as (min_{I}-max_{II}).

No	Type	Period P	Initial epoch T_0	Max_{I} (CR)	Max_{II} (CR)	min_{I} (CR)	min_{II} (CR)	Δmax	$\frac{\Delta\text{max}}{\sigma}$	A	$\frac{\Delta\text{max}}{A}$
1	Ell:	0.270841±0.000020	2454945.1622±0.0032	12.870±0.003	12.860±0.004	12.964±0.004	12.959±0.004	-0.010±0.005	2.000	0.104±0.006	-0.0962
2	EW	0.417856±0.000025	2454945.8432±0.0014	14.814±0.011	14.801±0.005	15.136±0.007	15.128±0.010	-0.013±0.012	1.083	0.335±0.009	-0.0388
3	EW	0.413660±0.000013	2455192.8152±0.0012	13.489±0.002	13.458±0.003	13.664±0.004	17.639±0.002	-0.031±0.004	**7.750**	0.206±0.005	-0.1505
4	EW	0.376831±0.000006	2455191.7896±0.0005	14.359±0.005	14.386±0.005	14.932±0.007	14.860±0.004	0.027±0.007	**3.857**	0.546±0.009	0.0495
5	EW	0.294039±0.000004	2455191.4051±0.0003	14.829±0.008	14.853±0.009	15.638±0.009	15.552±0.008	0.024±0.012	2.000	0.785±0.013	0.0306
6	EW	0.434912±0.000009	2455192.4772±0.0005	13.628±0.003	13.610±0.003	13.977±0.003	13.963±0.005	-0.018±0.004	**4.500**	0.367±0.004	-0.0490
7	EW	0.475366±0.000012	2455192.6380±0.0005	13.128±0.002	13.137±0.006	13.457±0.002	13.404±0.003	0.009±0.006	1.500	0.320±0.006	0.0281
8	EW	0.469085±0.000044	2455268.8822±0.0011	16.821±0.026	16.867±0.023	17.593±0.018	17.494±0.022	0.046±0.037	1.243	0.726±0.029	0.0634
9	EB	0.478130±0.000040	2455268.5270±0.0007	12.834±0.003	12.833±0.002	13.080±0.003	12.916±0.002	-0.001±0.003	0.333	0.247±0.004	-0.0040
10	EW	0.268768±0.000026	2455233.4364±0.0011	16.006±0.011	16.034±0.014	16.376±0.014	16.296±0.014	0.028±0.018	1.556	0.342±0.020	0.0819
11	EW	0.434548±0.000018	2455233.6290±0.0006	14.182±0.003	14.134±0.007	14.542±0.004	14.398±0.004	-0.048±0.007	**6.857**	0.408±0.008	-0.1176
12	E	0.411670±0.000054	2455261.8510±0.0015	15.920±0.010	16.227±0.016	16.550±0.016	16.341±0.011	0.307±0.019	**16.158**	0.323±0.023	0.9505
13	EW	0.345439±0.000049	2455262.1281±0.0011	15.884±0.009	15.901±0.009	16.226±0.008	16.181±0.010	0.017±0.013	1.308	0.325±0.012	0.0523
14	EW	0.415351±0.000024	2455261.9148±0.0006	14.545±0.005	14.553±0.003	14.798±0.003	14.796±0.003	0.008±0.005	1.600	0.245±0.004	0.0327
15	EW	0.456908±0.000028	2455261.8903±0.0010	14.523±0.004	14.515±0.004	14.761±0.003	14.756±0.004	-0.008±0.006	1.333	0.246±0.005	-0.0325
16	EA	0.336481±0.000020	2455261.9982±0.0005	15.318±0.006	15.312±0.005	15.918±0.007	15.798±0.007	-0.006±0.008	0.750	0.606±0.009	-0.0099
17	EA	0.642197±0.000012	2455261.1514±0.0014	15.732±0.026	15.718±0.032	16.401±0.016	16.385±0.016	-0.014±0.041	0.341	0.683±0.036	-0.0205
18	Ell	0.292492±0.000019	2455261.8475±0.0005	14.120±0.002	14.113±0.002	14.246±0.002	14.240±0.002	-0.007±0.003	2.333	0.133±0.003	-0.0526
19	EW	0.245108±0.000006	2455312.3737±0.0006	15.614±0.004	15.606±0.002	15.700±0.003	15.682±0.003	-0.008±0.004	2.000	0.094±0.004	-0.0851
20	E	0.266685±0.000006	2455311.0962±0.0012	15.073±0.001	15.048±0.002	15.169±0.001	15.126±0.002	-0.025±0.002	**12.500**	0.121±0.002	-0.2066
21	EW	0.248007±0.000005	2455312.6068±0.0009	16.840±0.006	16.827±0.006	17.105±0.006	17.092±0.005	-0.013±0.008	1.625	0.278±0.008	-0.0468
22	EA	0.433131±0.000008	2455312.7456±0.0004	15.753±0.021	15.777±0.019	16.556±0.022	16.186±0.025	0.024±0.028	0.857	0.779±0.029	0.0308
23	EW	0.292380±0.000003	2455312.4524±0.0003	16.667±0.006	16.651±0.003	17.195±0.005	17.168±0.005	-0.016±0.007	2.286	0.544±0.006	-0.0294
24	EB	0.282757±0.000003	2455312.3299±0.0002	15.143±0.003	15.167±0.004	15.666±0.004	15.363±0.004	0.024±0.005	**4.800**	0.499±0.006	0.0481
25	EW	0.241996±0.000001	2455312.3475±0.0001	14.825±0.004	14.801±0.004	15.631±0.005	15.525±0.004	-0.024±0.006	**4.000**	0.830±0.006	-0.0289
26	EW	0.361080±0.000002	2455312.3549±0.0002	13.035±0.002	13.049±0.002	13.314±0.001	13.300±0.001	0.014±0.003	**4.667**	0.265±0.002	0.0528
27	EB	0.445393±0.000016	2455278.1853±0.0012	13.557±0.004	13.624±0.005	13.795±0.004		0.067±0.006	**11.167**	0.171±0.006	0.3918

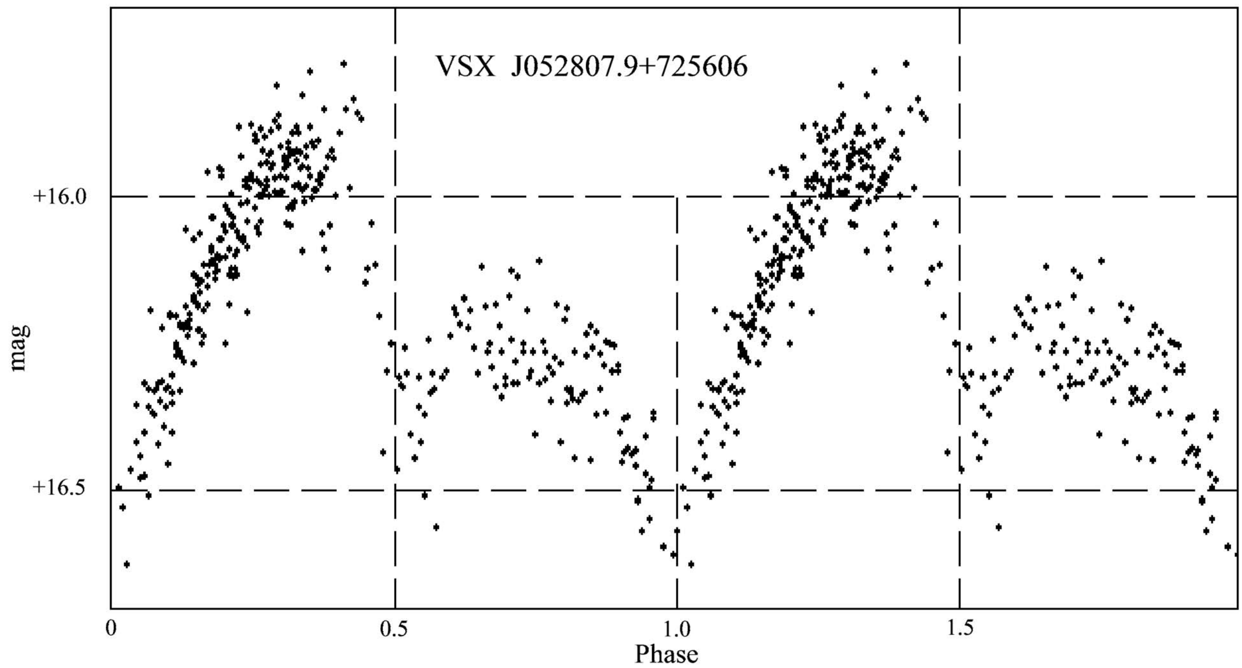

Fig.4. The phase curve of the star VSX J052807.9+725606.

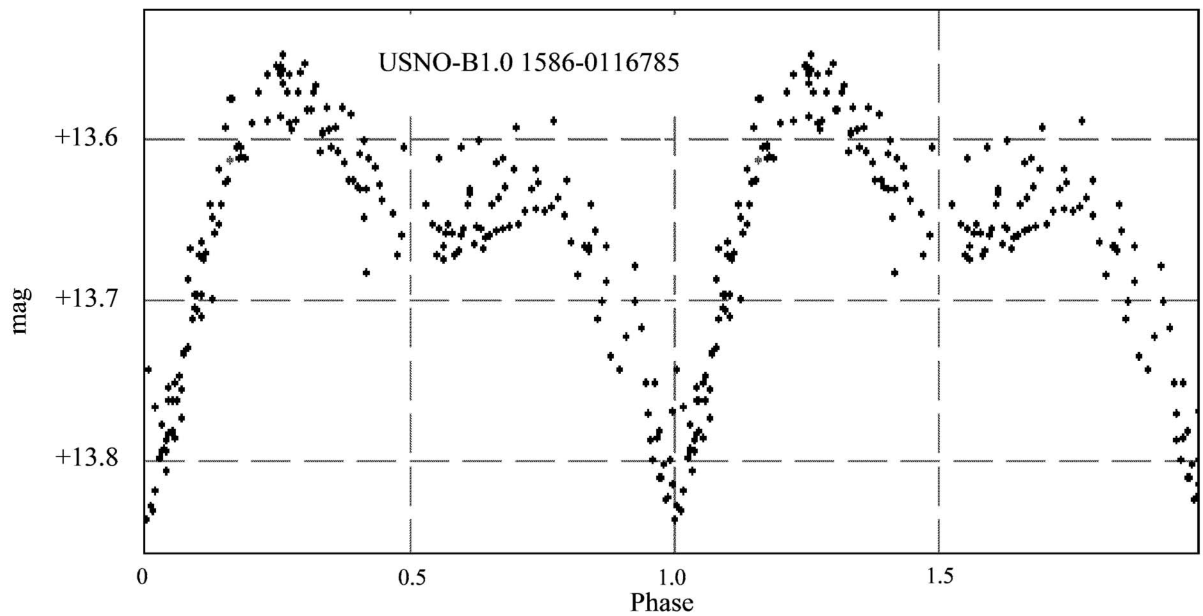

Fig.5. The phase curve of the star USNO-B1.0 1586-0116785.

2. between Δmax/A and the value of the period (Fig.2);
3. between Δmax and the value of the period (Fig.3).

We found no statistical dependence between the period and Δmax/A or Δmax. But there are 2 points, which are separated from the “main cloud”, they are marked by squares on the plots. The point No.1 corresponds to the star No 12 in the Tables 1 and 2, USNO-B1.0 1629-0064825 = VSX J052807.9+725606. The point No. 2 corresponds to the star No. 27, USNO-B1.0 1586-0116785.

The most unusual curves

Two stars, which marked on the Fig 1-3 exhibits the largest difference between magnitudes in maxima. The phase curve is shown on the Figure 4. The first of them, No.1 = VSX J052807.9+725606, is very similar to the well known binary system V361 Lyr. Both of these stars exhibit a huge difference in maxima, the first maximum is brighter than the second one. Besides, in both cases the phase of the first maximum is not 0.25, but 0.30, and the phase of the secondary minimum is not 0.50, but 0.52 for V361 Lyr and 0.54 for VSX J052807.9+725606. According to the classical model of V361 Lyr, the cause of this asymmetry is a presence of a hot spot in the photosphere of the first component. The accretion matter streams through the inner Lagrangian point from the second component to the first one, however it doesnt form the accretion disk, but, deviated by the Coriolis force from the line of centres, impacts into the photosphere of the accretor with a shift towards the orbital motion. The shock appears, which heats the surrounding plasma, and a hot spot is formed in the atmosphere. We assume that the same mechanism is present in VSX J052807.9+725606. The more detailed investigation of this star had been described in the paper “A New Binary System with an Unusual Asymmetric Light Curve” (Virnina and Andronov, 2010).

Another interesting binary system, which was marked by No. 2 (No. 27 in the Tables) shows rather big asymmetry too, but doesnt exhibit a confident shift of the secondary minimum. The phase curve of this star is shown on the Figure 5.

Taking into account the shape of the phase curve, we may assume the presence of a cool spot on one of the stars, which is visible near the phase of the second maximum. This version of the asymmetry could be confirmed during the further observations.

Conclusions

We’ve analyzed 27 newly discovered binary systems. Ten of them have the curves with statistically significant asymmetry of maximums, which means that more than 1/3 of the stars investigated in this paper have asymmetrical curves. One of the most probable solutions for these stars is the presence of a cold or a hot spot (or group of spots) in the photosphere of one or even both of the components. The question of stability of these spots could be solved due to further multicolor photometrical and spectroscopic observations.

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