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Editor-in-chief **Radek Kocián**

Participants of the conference in front of the observatory

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INTRODUCTION

Each year in November, when the full moon makes variable star observing difficult, the Variable Star and Exoplanet Section of Czech Astronomical Society holds a national conference on variable stars, stellar astrophysics in general and on extrasolar planets. For the first time, the conference took place in Ostrava, the third largest city in the Czech Republic, when we accepted an invitation from local Observatory and Planetarium of Johann Palisa. The 2011 conference was held on a weekend from November 11th to November 13st.

Our conferences on variable star research provide unique opportunities for meetings between professional and amateur astronomers and have become a crucial platform for exchanging information and sharing knowledge. These events help to keep the local astronomical community alive and active.

I would like to express gratitude to all authors for their talks and posters and to all participants for their contribution to the discussions!

Luboš Brát
- president of Variable Star and Exoplanet
Section of Czech Astronomical Society
Pec pod Sněžkou, November 21st 2011

NOTES

The scientific content of the proceedings contributions was not reviewed by the OEJV editorial board.

AV CMi: preliminary results from photometric study

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Abstract: Preliminary results of one year photometric study of eclipsing binary system AV CMi are presented. Possible low-mass third body on unusual orbit in this system was discovered by Liakos & Niarchos (2010). Our measurements confirmed observed dips of brightness in the light curve called transit of third body. Two measurements were used for identification of host star but neither allows convincing decision. The results are contradictory and thus are opposed of three-body system. Blend of two eclipsing systems in the same position on the sky was proposed for this reason. Accuracy of our astrometric measurements did not allowed to detect an awaited shift in position of centroid during eclipse.

Abstrakt: V příspěvku jsou prezentovány předběžné výsledky z jednoho roku fotometrického studia zákrytové dvojhvězdy AV CMi. Liakos & Niarchos (2010) objevili možné třetí těleso s nízkou hmotností na neobvyklé dráze. Naše měření potvrdila pozorované poklesy jasnosti označované jako tranzity třetího tělesa. Pro identifikaci jeho mateřské hvězdy bylo využito dvou měření, ani jedno však neumožňuje jednoznačné rozhodnutí. Výsledky jsou navíc protichůdné a tak odporují představě tří těles. Jako možné vysvětlení byla proto navržena projekce dvou zákrytových dvojhvězd na stejné místo hvězdné oblohy. Bohužel přesnost našich astrometrických měření neumožnila detekovat očekávaný posuv v pozici centroidu během zákrytů.

AV CMi (2MASS J07091084+1211190, SON 10225,
R.A.= $07^h09^m10^s.84$ *DEC.= +12°11'19".1 Equinox: 2000.0*)

(type EA, period 2.277751 day, amplitude 11.8 – 12.1 mag. (pg))

Introduction

AV CMi is an eclipsing binary system of Algol type discovered by Hoffmeister (1968) on Sonneberg's photographic plates. Later Gessner (1973) determined from Sonneberg's photographic observations that object changes its brightness between 11.8 and 12.1 mag. However, his period P = 1.13888 d is a half of the real one and the published phased light curve is wrong. This phase light curve consists of deep primary minimum and shallow secondary one. Svechnikov & Kuznetsova (1990) used these incorrect light curve parameters as input values for determination of the system properties from statistical dependencies between binary stars and their photometric light curves. Thus they found incorrect parameters as mass ratio $q = m_2/m_1$~0.29, inclination angle i = 72°, semi-major axis a = 5.65 R_S, radii of components r_1 = 0.282 a, r_2 = 0.269 a and their spectral types (F0)+[G5IV].

The system was observed very rarely since the discovery and better value of period P = 2.277751 d was published only by Liakos & Niarchos (2010), who observed AV CMi to obtain a complete phase light curve in Bessel bands V, R, I. They analyzed brightness variability using the code PHOEBE 0.29d (Prša & Zwitter 2005) and found most probable value of mass ratio q~ 0.71. Their utilization of the temperatures adopted from spectral type published by Svechnikov & Kuznetsova (1990) is controversial point because their estimated results were based on the bad value of orbital period. Then, parameters published by Liakos & Niarchos (2010) must be adopted circumspectly for this reason. They used fixed temperature of primary T_1 = 7 000 K together with a few other input parameters from which they calculated temperature of secondary T_2 = 7 005(6) K, inclination angle i = 83.8°, radii of primary and secondary star r_1~0.19a, r_2~0.18a and other parameters. They also published information about eccentricity of orbit of secondary star e = 0.11(1). Liakos, Mislis & Niarchos (2011) published revised parameters of the system from new observations. Their models from Phoebe 0.29d were calculated with better value of surface temperature of primary star 7900 K corresponding to B-V 0.14-0.2 mag. Determined parameters are: secondary surface temperature T_2 = 7 897(8) K, inclination angle i = 83.6(1)°, radii of components r_1 = 2.38(5) R_s , r_2 = 1.72(4) R_s and mass ratio q = 0.843(3).

Small depressions in brightness with period P_T ~ 0.52 d, amplitude Δm ~0.03 mag (possible deeper in longer wavelength – I band) and duration d ~3.3 h were surprisingly discovered by Liakos & Niarchos (2010) in light curve. Authors noted that this effect is caused by low-mass third body in the system that regularly partially covers surface of the orbited stars. They called the observed changes as transits and mentioned that eclipse of third body is not detectable due to very small amplitude. Interesting low value of period of transit compared with orbital period of binary pair (ratio is only 1:4.4) indicates that the third body has to orbit around one of binary component (hereafter called host star). However, authors were not able to decide which star is a host one because both stars have similar temperatures.

Liakos, Mislis & Niarchos (2011) published more accurate ephemeris of transits and tried to identify host star of third body from a shape of five transits by program PhoS-T (Mislis et al. 2011). Their results from the modeling of light curves by PhoS-T are not convincing but they noted that primary star as host star is more realistic. One of the problems could be variability in the shape of transits which can be explained by non-spherical shape of host star, changes on the surface of the host star or by observational errors. This variation in the shape of transit would indicate blend theory discussed below. The other problem is similar temperatures of both stars and their radii. The third body orbited around primary or secondary star will show similar shape of transit in both cases. Determination of host star by this way is for mentioned reason generally problematic. Our suggestion for determination of host star from photometric observations is mentioned hereafter.

Verification of existence transits in light curve

Our team started at the beginning of 2010 with verification of observed dips in a light curve. We made simultaneous observations of one transit in the night 26/27 January 2010 on four observational places in the Czech Republic using different equipments with following photometric filters: R (Liška), I (Brát), V (Uhlář), C-clear (Trnka). Our results (see Figure 1) are similar to the published ones in Liakos & Niarchos (2010). Detailed analysis will be presented in future paper.

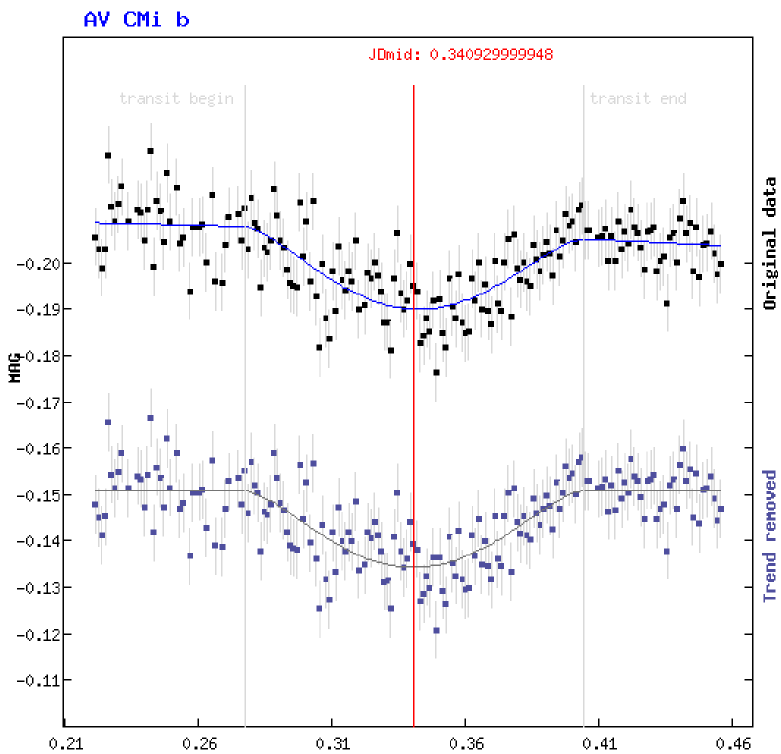

Figure 1: Observed transit from 26/27 January 2010 (Liška) fitted by online model fitting procedure http://var2.astro.cz/tresca/ (Pejcha 2008, Brát 2008).

The typical process for study of eclipsing binary system is collecting a lot of photometric measurements to create phased light curve. The necessary step is an improvement of the orbital period that is impacted by an apsidal motion in system AV CMi. This information had not been mentioned in previous articles. We used all available times of minima from online O-C gateway (Paschke & Brát 2006) including our own new ones. The times of minima from our measurements were determined by program AVE (Barberá 1999). We noted that many times of minima are influenced by transiting effect and more precise values will be obtained after their subtraction which is planned in future.

The parameters of apsidal motion were calculated using Matlab code published by Zasche et al. (2009). Results from modeling of changes in O-C diagram are shown in the Figure 2. Found output parameters: period P = 2.277750 ± 0.000004 d, mid-epoch HJD = 2438379.71 ± 0.02 d, eccentricity e = 0.11 ± 0.05, period of apsidal motion U = 187 ± 84 yr, argument of periastron Ω = 297 ± 5 yr and rate of periastron ω = 0.012 ± 0.01 °/cycle were calculated with sum of the square residuals χ = 0.012. However, we are going to improve these parameters and their accuracy using original photographic measurements from Sonneberg observatory (Hoffmeister 1968, Gessner 1973).

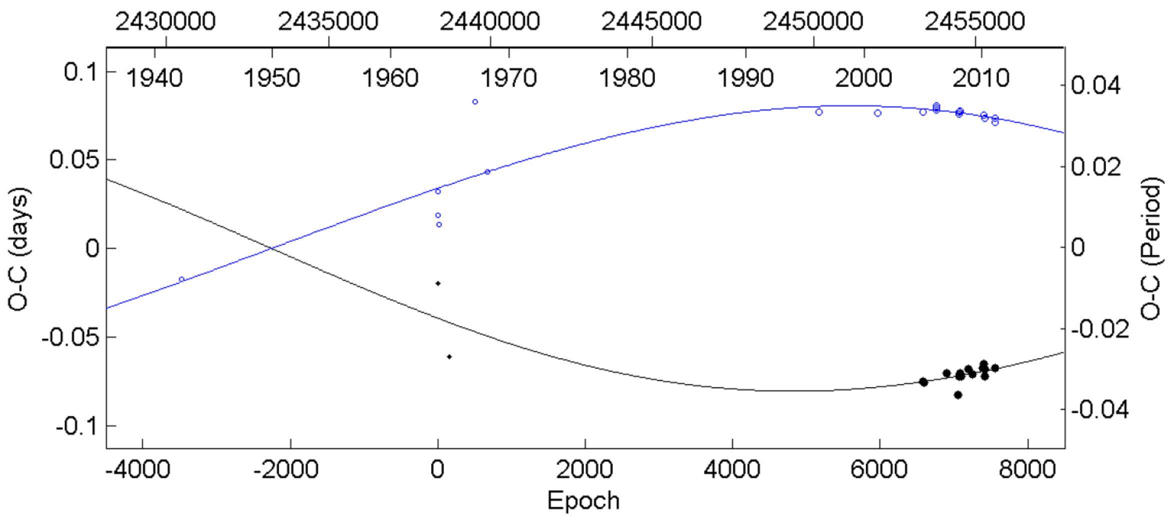

Figure 2: O-C diagram of AV CMi system, black dots are primary minima and blue circles are secondary ones. The graph shows calculated apsidal motion with period U = 187 ± 84 yr in the system.

Host star of third body

Triple systems are stable when two bodies create close pair and third body orbits at a great distance around the couple. Orbital periods for stable triple systems would be in ratio $P_{in}:P_{out}$ < 1:8 that come out from dynamical simulations of three bodies systems (dynamical stability of triple system is depending also on other parameters such as eccentricity and masses all three bodies; stability criteria are mentioned e.g. in Orlov & Petrova 2000). Exemplary system probably on the edge of stability is λTau $P_{in}:P_{out}$ = 1:8.3 (Fekel & Tomkin 1982). The period of eclipse and the period of transit in the system of AV CMi are P ~ 2.28 d and P_T ~ 0.52 d that corresponds to ratio $P_T:P$ only 1:4.4. We deduce two pieces of information from this ratio. The third body has to orbit around one of stars and its path should not be apparently stable. Theoretical aspect of orbital stability is in conflict with observed value of period ratio in AV CMi system. But it can be explained as a short time view on the system just before their break up or by blend model presented in next section.

Determination of host star was performed by measurements of shape of transits (Liakos, Mislis & Niarchos 2011). Their results are not conclusive due to reasons mentioned above. We present other possibility. We tried to catch situation when all three bodies are in one line together with our direction of view. Primary or secondary eclipse and transit take place simultaneously at the time. When inclination angle is close to 90° then we expect partially or even full cover of transit. When the shape of transit will be deformed during primary eclipse, host star is primary star or in opposite situation secondary star. Our chance to catch this situation is not high but regarding to published value i ~ 83.6° (Liakos, Mislis & Niarchos 2011) is real.

We have observed first situation (primary eclipse and transit) in night 22/23 October 2011 (Liška – Masaryk University Observatory in Brno, RL 62/278, CCD ST-8, filters *BVRI*) and second situation (secondary eclipse and transit) was found in archive of measurements from 27/28 October 2006 (Svoboda – Private Observatory in Brno, RL 20/100, CCD ST-7, filters *BVRI*). Data were processed by standard photometric procedure with software C-Munipack 1.1.28 (Motl 2009). After that synthetic model of the light curve from Phoebe 0.29b and parameters from Liakos & Niarchos 2010 were applied for subtraction of main trend caused by eclipse (Figure 3 top). Unfortunately neither of both datasets shows awaited changes in shape of transit clearly (Figure 3 bottom). Difference between theoretical prediction and observations can be explain by not precise alignment all of three bodies in one line with direction of view (different phase timing or lesser inclination angle than 83,6°) or it can be a sign of mistake in concept of three body system (discussion in next section). However, we note that transit subtracted from secondary eclipse shows smaller amplitude of transit than in case of primary eclipse. We will try to observe in the same constellations in the future. Nevertheless direct identification of host star and confirmation of third body system will be conclusive by accurate spectroscopic observations. A low amplitude changes (order m/s) are awaited in radial velocity curve of host star with period P_T.

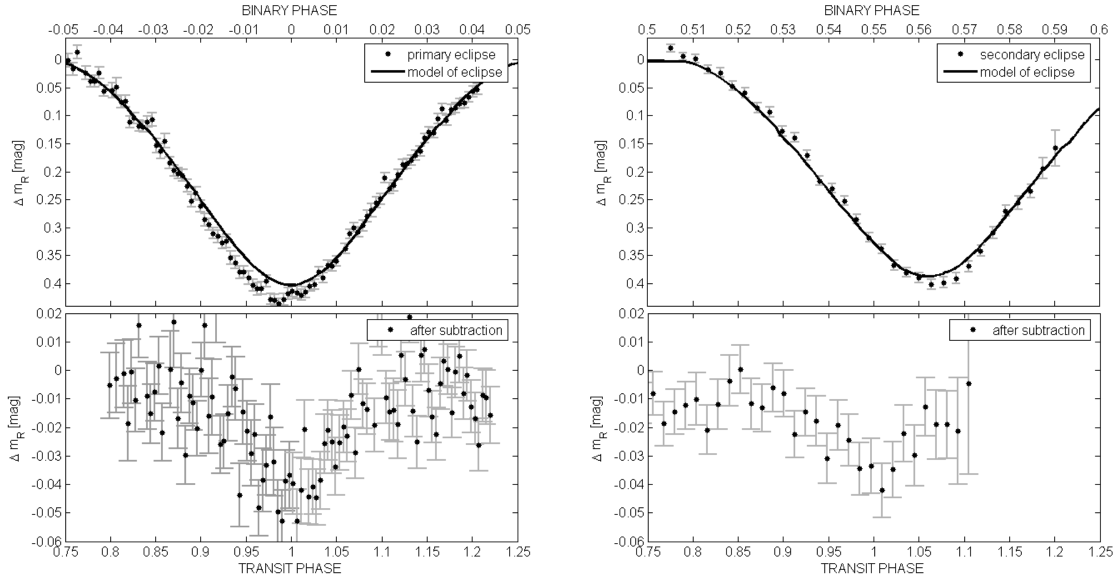

Figure 3: Light curves of primary eclipse (22/23 October 2011, Liška, *R*-band) and secondary eclipse (27/28 October 2006, Svoboda *R*-band) with synthetic light curves calculated by Phoebe 0.29b (top graphs) and subtractions shown clear transits in both light curves (bottom graphs).

Test of Blend scenario

The blend theory known from searching for transiting exoplanets assumes one bright star (invariable) and background eclipsing binary (BGEB) near to the same position in the sky and in the frame. All three stars are blend in one "star" (for ideal case in one Airy disc). Flux measurement by aperture photometry is determined as flux all three stars together. Amplitude of variation of BGEB would be much lower due to bright star. Existence of two independent star systems is detectable by measurements of position of centroid in the frames during the eclipses of BGEB. The blend effect is often shown in Position-Flux diagram where will be prove as distinct shift of position star in the minima of the flux in comparison with position in maximum of flux. Detailed description of blend is e.g. in Batalha et al. (2010).

The blend scenario was proposed and tested for explanation of observed dips in the light curves. This test is known from detection transits of exoplanet as false-positive method but we expected object AV CMi as a blend of two separated and gravitational independent eclipsing systems, similar situation as object OGLE-LMC-ECL-16549 described by Graczyk et al. (2011). Position of centroid of AV CMi measured during primary or secondary eclipses could bring information about blend by shift in sub-pixel scale. We have measured astrometric position of AV CMi in the most of frames (only *R* band) which were observed in MUO Brno with RL 62/278 and CCD ST-8 (SBIG) but changes of position were not detected unfortunately. Measured positions of centroid were corrected by rotation and by movement characteristic for all stars on the frames due to inaccurate set up of the mount of the telescope. 6 stars around AV CMi were used for this reason. Positions of centroid in X-axis and Y-axis are plotted in a graph as dependence to relative flux (Figure 4). Our results evince only random variation of position around mean values and show no visible shift in either axis. We noted that 0.1 pixel is 0.07 arcsec in the sky. We propose small distance between two eclipsing systems or even 4-body gravitational boundary system (double eclipsing feature) as a suitable explanation of AV CMi nature.

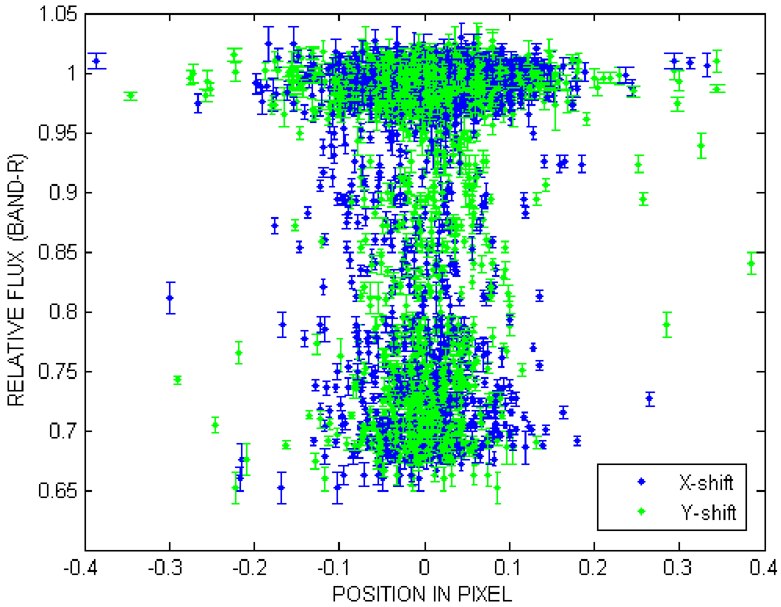

Figure 4: Test of blend shown as diagram Position-Flux. No evidence shift of position of centroid in X-axis or Y-axis was detected during eclipses.

Results

Preliminary results of one year photometric measurements of eclipsing system AV CMi were presented in this paper. Apsidal motion of eccentric orbit (e = 0.11 ± 0.05) with period U = 187 ± 84 yr was identified in the eclipsing system. Existence of observed dips in light curve was confirmed by simultaneously measurement in 26/27 January 2010. Complicated identification of host star of third body was performed by measurements of simultaneous eclipsing all three bodies during primary respectively secondary eclipse. Host star would be primary one in situation when measurements of primary eclipse will contain deformed shape of transit. Deformation of transit in secondary minimum would mean that secondary star is host one. Our observations have not brought unfortunately significant results. It can be explained as a different phase timing of both processes (main eclipse and transit) or by wrong orbital parameters e.g. inclination. It can be also a sign that AV CMi is not a triple system; for this reason the blend scenario was suggested. The blend effect of two separated eclipsing systems was presented and tested by measurements of astrometric position on the frames. Unfortunately this possibility was not confirmed by our measurements. It was probably caused due to insufficient accuracy of our astrometric measurements. We propose also system consisted of two bounded eclipsing pairs for which no test of blend is successful.

Acknowledgments

Authors are very grateful to Ondřej Pejcha and his helpful suggestions about blend scenario and its test. Special thank belongs to Zuzana Lišková for useful discussion. This work has been supported by MUNI/A/0968/2009 and by grant GD205/08/H005.

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Blazhko effect and RR Lyrae type stars – light curve analysis

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Abstract: For about fifteen years there is a relatively simple instrument for a determination of physical parameters of RR Lyrae type stars through the light curve analysis (e.g. Jurcsik, 1998, Kovács, 1998). The method is based on a phased light curve fitting via goniometric functions. In a large percentage of RR Lyraes the modulation of the light curve (known as a Blazhko effect) is present. This behaviour in an addition to the light curve fitting method brings some pitfalls and specifics in the problem, which is discussed.

Abstrakt: Už přibližně patnáct let je k dispozici relativně jednoduchý nástroj k určení fyzikálních parametrů hvězd typu RR Lyrae analýzou fotometrických měření (např. Jurcsik, 1998, Kovács, 1998). Základ těchto metod spočívá v modelaci fázové světelné křivky pomocí goniometrických funkcí. U nezanedbatelného množství hvězd tohoto typu navíc dochází k modulaci světelné křivky známé jako Blažkův jev. Tento jev společně s metodou modelace s sebou ovšem nese určitá úskalí a specifika, která jsou diskutována dále.

In the nineties of the 20th century it was shown, that there are simple relations between so called Fourier parameters and basic physical parameters like the metallicity and the luminosity (Kovács, 1998). These Fourier parameters are derivative of light curve fitting via goniometric functions. If we want to describe the light curve with the sum of sines or cosines, we strictly have to analyse a well-covered light curve with regularly spaced points with a low noise level. Otherwise the Fourier coefficients and also the physical parameters are not reliable. It was shown, that the relations can be also used in the case of Blazhko stars. If the star exhibits the Blazhko effect, there could be a problem with good coverage of the folded light curve, because the long based observations are needed.

There are many statistical approaches to determine the accuracy of the fit and according to this accuracy we can estimate the "right" order. But – is the fit with the lowest error really the best? In many cases it is not the truth. The higher order of the fit means higher accuracy of the fit and lower error, but it also means that the noise could be fitted. So the visual inspection and the individual approach to each light curve are recommended. The better quality the data are, the higher order of the fit we can use.

Typically the data from large sky surveys like ASAS and NSVS are not (in most cases) of a good quality to determine the physical parameters by analysing them. As the relations are based on the V Johnsons standard band light curves, to calibrate data to this system the multicolour photometry is needed. The fact that the method can be used for stable and also for Blazhko stars, gives us the opportunity to try to find the differences between Blazhko and non-Blazhko stars.

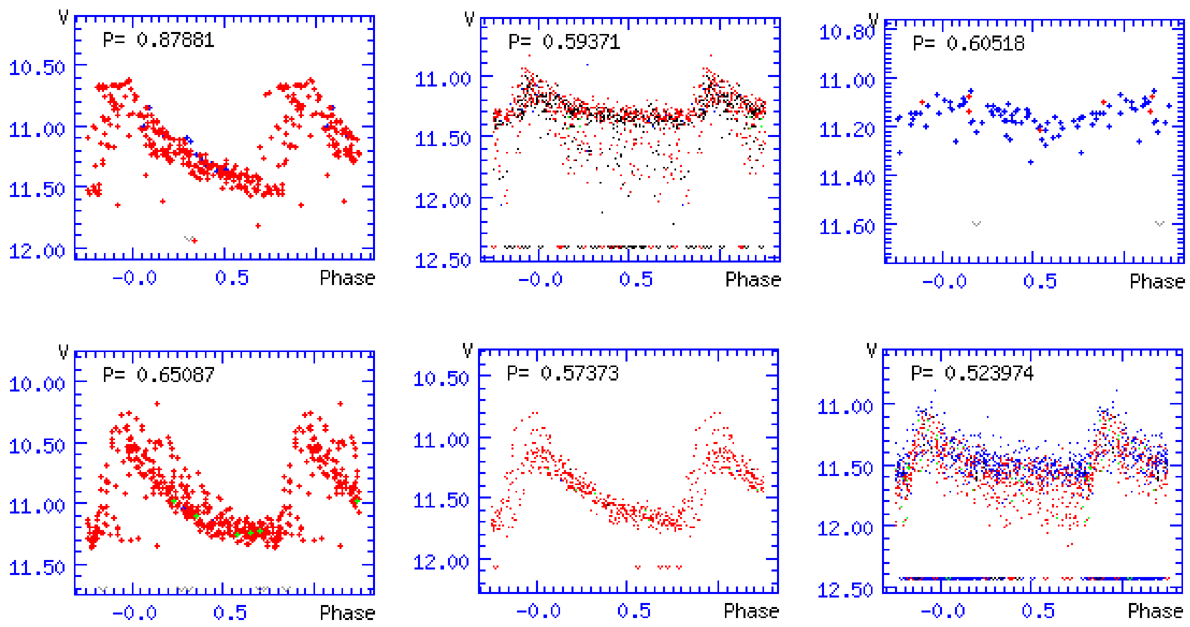

Figure 1: The examples of high-noise-level stars from ASAS survey, which were analysed (Szczygiel, 2009).

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New variable stars CzeV 245, SvkV 23, CzeV 270 and CzeV 323

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Abstract: In this paper there are presented four new discovered variable stars. One pulsating RRab type, two eclipsing binaries EW type and one eclipsing binary Algol type with rapid apsidal motion.

Abstrakt: V tomto článku jsou prezentovány čtyři nově objevené proměnné hvězdy. Jedna pulzující typu RRab, dvě zákrytové typu EW a jedna zákrytová typu Algol, u které bylo zjištěno rychlé stáčení přímek apsid.

Observation and data analysis

GSC 00330-01476 = CzeV245 (R.A. = $14^h55^m24.07^s$ DEC. = +04°14'43.2" Equinox: 2000.0), type RRab has been discovered on April 20, 2011 by Martin Mašek from Liberec, Czech Republic while observing the known eclipsing binary GSC 00330-01394. The observation was conducted by a 70mm f/10 refractor scope with 0.5x reducer and Meade DSI CCD camera.

The confirmation of the discovery was accomplished on May 3, 2011. New variable star has been preliminarily published in the Czech Variable Star Catalogue as CzeV 245. There have been determined these elements for CzeV 245: Max. = HJD 2455672.4880 + 0.513328*E, 13.4 – 14.3 mag (V), using own observations and data from ASAS-3 survey.

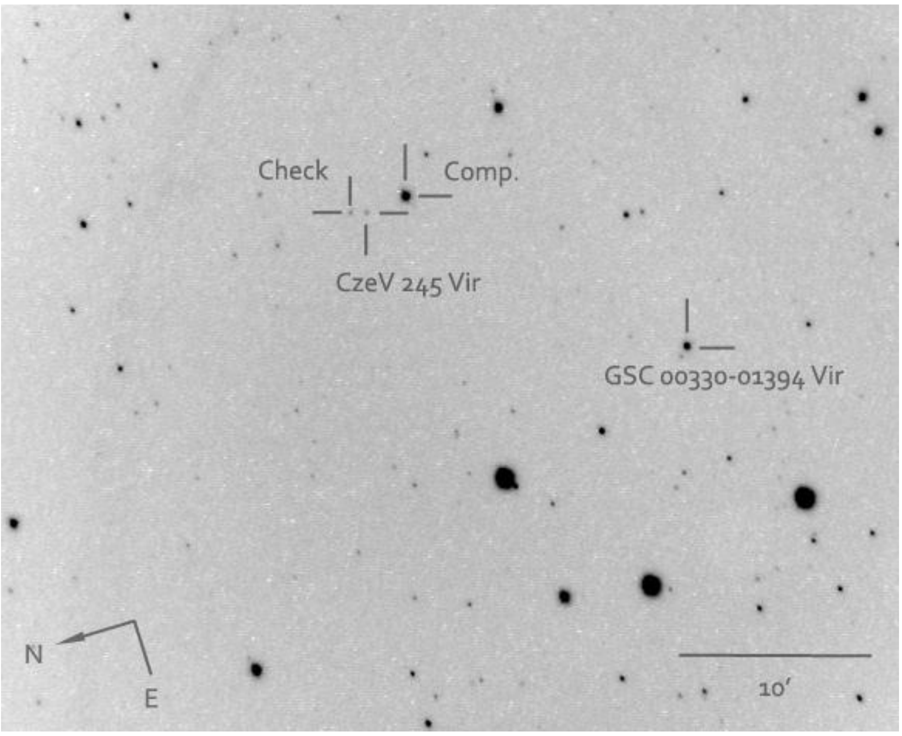

Figure 1: Finding chart for the new variable CzeV245. Comp. = GSC 00330-00575.

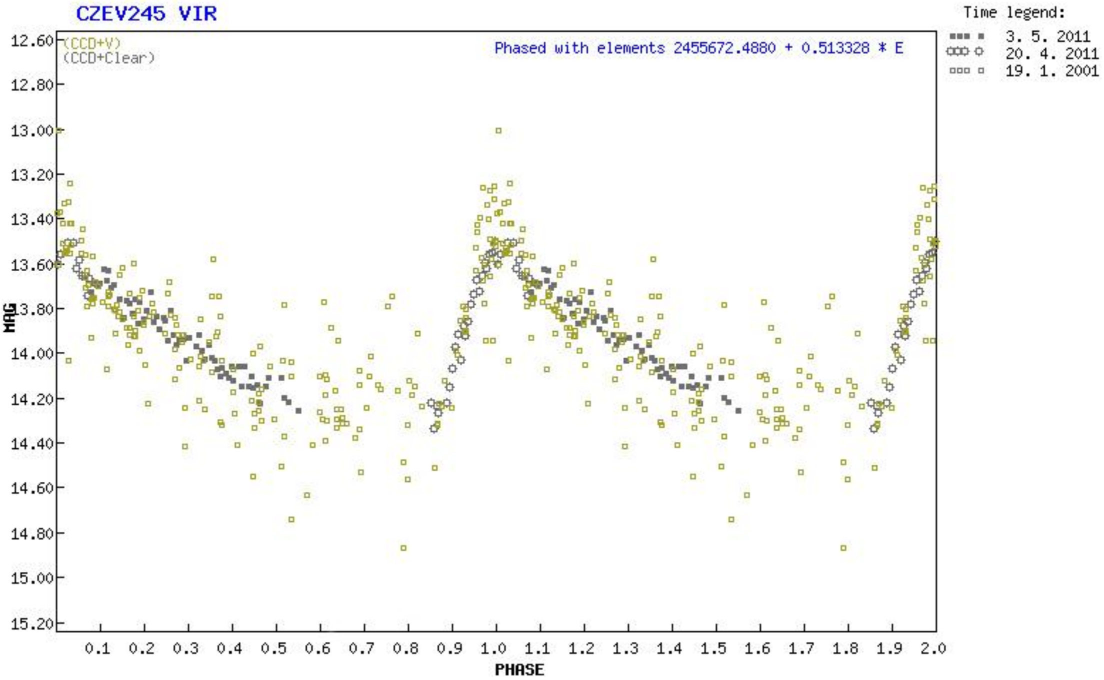

Figure 2: Phased light curve of CzeV 245.

GSC 02761-01817 = SvkV 23 (R.A. = 22^{h}53^{m}48.54^s DEC. = +37°00’42.7” Equinox: 2000.0), type EW has been discovered in July 2011 by Martin Mašek on archival DSLR images of Robert Barsa. Pictures were taken on July, 12, 2010 at Roztoky observatory, Slovakia, during the Variable 2010 expedition, which purpose was to observe the minima of SW Lac eclipsing binary. The discovery observation was conducted by 80mm f/7.5 refractor and DSLR Canon EOS 350D. This is the first variable star which has been discovered in Slovakia by DSLR camera.

New variable star has been preliminarily published in the Slovak Variable Star Catalogue as SvkV 23. There have been determined these elements for SvkV 23: Min. I = HJD 2455798.50234 + 0.3499823*E, 12.25 - 12.60 mag (V), using own observations and data from SuperWASP survey. It seems that there is light O‘Connell effect present in the system.

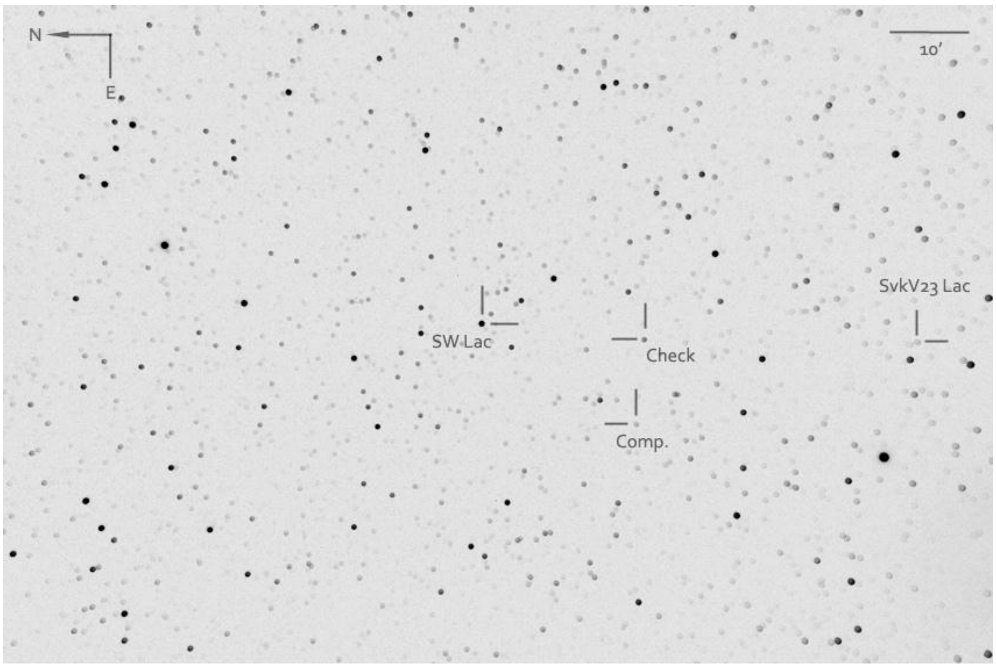

Figure 3: Finding chart for the new variable SvkV 23. Comp. = GSC 03215-02495.

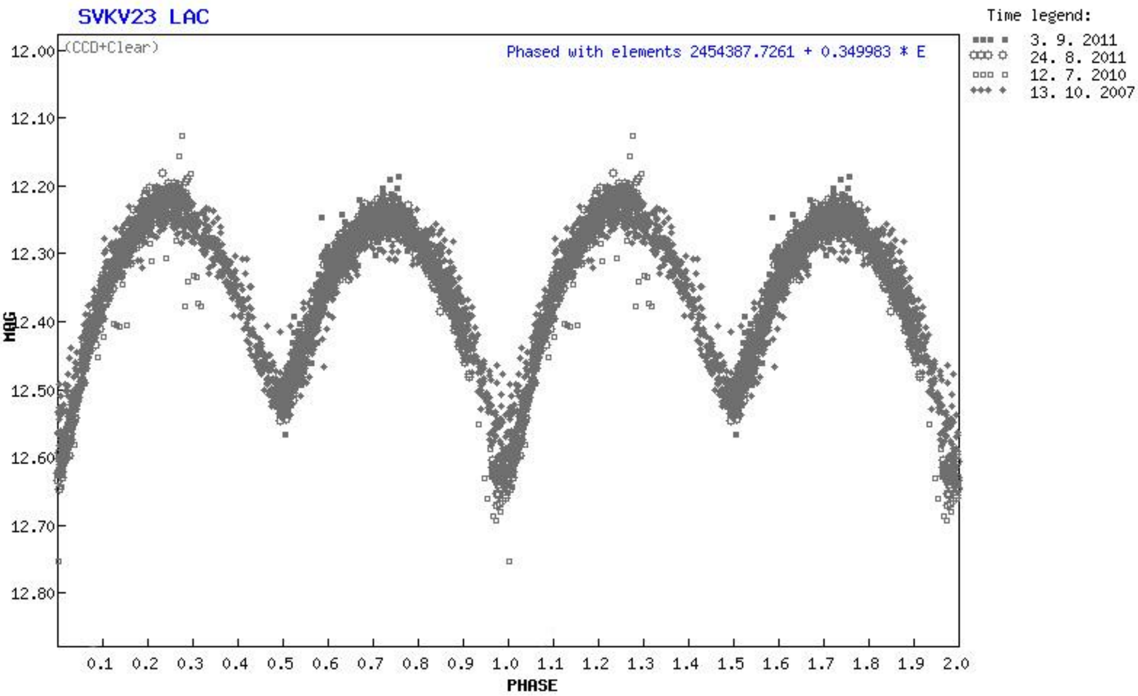

Figure 4: Phased light curve of SvkV23.

GSC 02712-01201 = CzeV 270 (R.A. = $21^h34^m57.64^s$ DEC. = +35°12'51.5" Equinox: 2000.0), type Algol, amplitude 10.65 - 10.90 mag (V), has been discovered on August 25, 2011 by Martin Mašek at Pec pod Sněžkou, Czech Republic, during the Summer camp for observers of variable stars. The discovery observation was conducted by Zeiss Sonnar 180mm lens and DSLR Canon EOS 1000D. This is the first variable star discovered in Czech Republic using DSLR camera. In the rich star field there has been captured around 10 000 stars. During the night was observed 15 different variable stars including CzeV 270 in one field of view. There have been successfully obtained minima of 9 known eclipsing binaries.

Preliminary period of CzeV 270 has been determined upon the SuperWASP survey. Consequently, there was organised a campaign, in which the next minima have been observed by Radek Dřevěný from Znojmo (200mm f/3.3 reflecting scope), Hana Kučáková from Ostrava (200mm f/6 reflecting scope) and Martin Mašek from Hodkovice nad Mohelkou (200mm f/5 reflecting scope). It has been found out that the secondary minima occurs out of phase 0.5. Based on archival data from SuperWASP survey and recent observations it has been constructed an O-C diagram which shows period changes during years 2004 – 2011. Star system shows fast rotation of the apsidal line.

Upon observations from 2011, there have been determined these elements: Min. I = HJD 2455832.54504 + 1.87778*E.

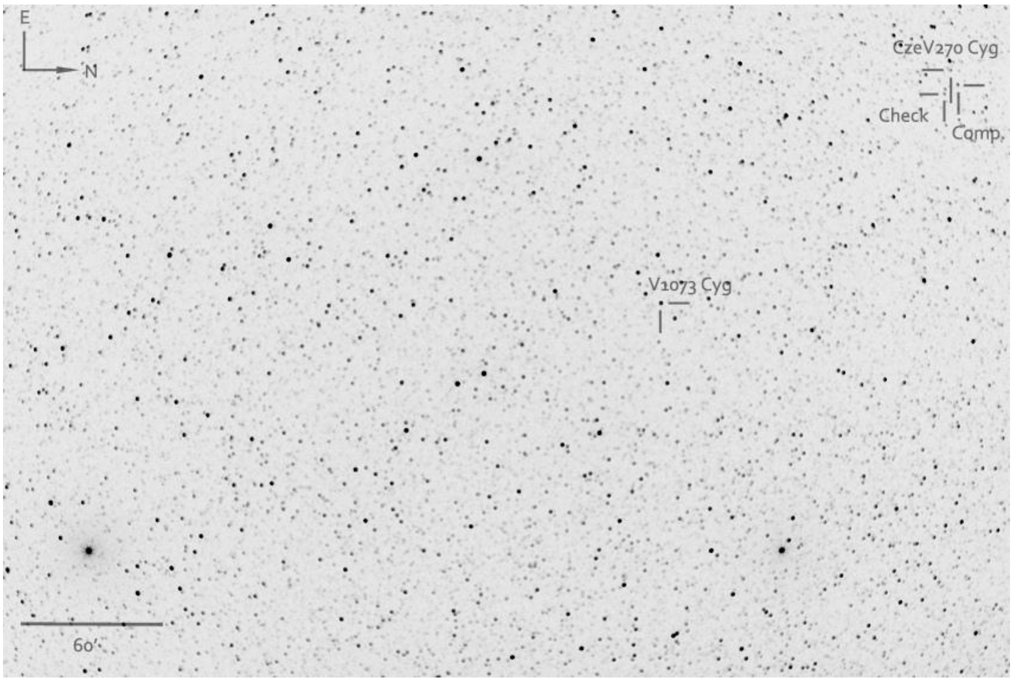

Figure 5: Finding chart for the new variable CzeV 270. Comp. = GSC 02712-00869.

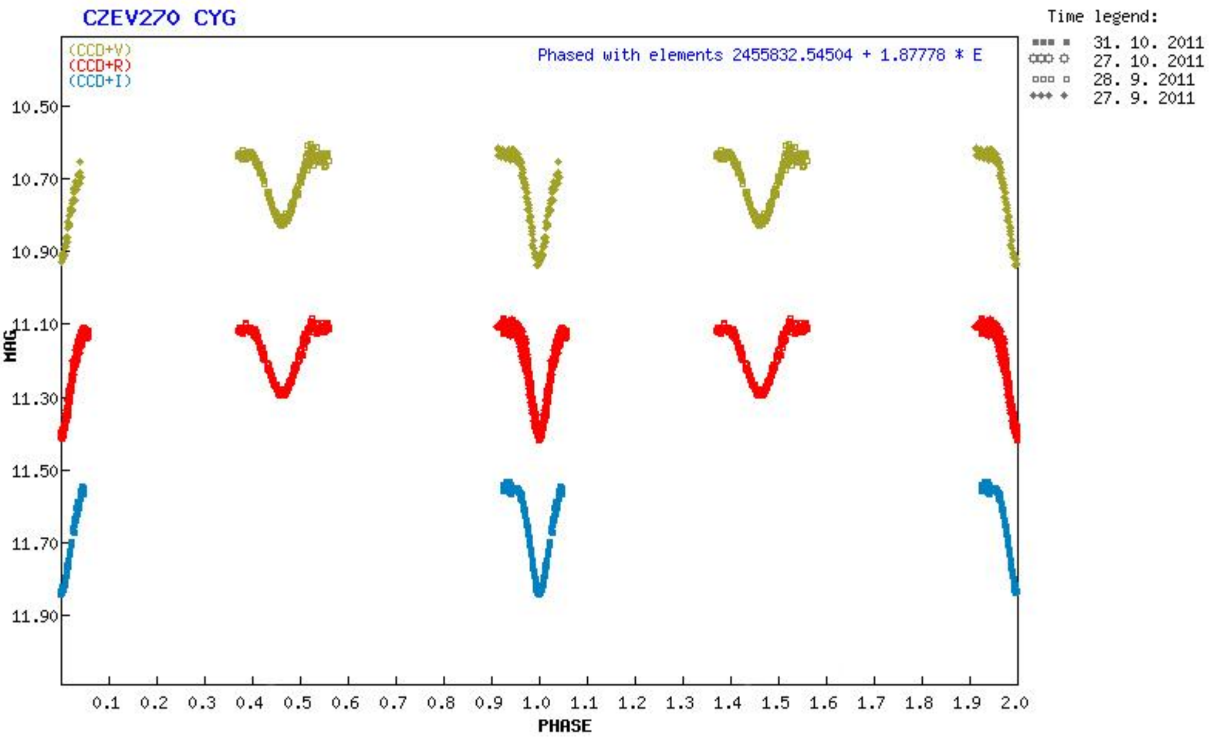

Figure 6: Phased light curve CzeV 270 in V, R and I photometrical filtres and clear.

HJD	error	Type	O-C	Observer	Published
2453231.5098	0.006	Min I	-0.0468	SWASP	-
2453232.5004	0.005	Min II	0.0048	SWASP	-
2453954.5382	0.005	Min I	-0.0368	SWASP	-
2453955.4890	0.007	Min II	-0.0250	SWASP	-
2454308.5444	0.004	Min II	-0.0280	SWASP	-
2454322.6280	0.006	Min I	-0.0292	SWASP	-
2455832.5450	0.0037	Min I	0.0000	R. DŘEVĚNÝ	B.R.N.O.
2455833.4142	0.0037	Min II	-0.0699	R. DŘEVĚNÝ	B.R.N.O.
2455866.3483	0.0002	Min I	-0.0002	H. KUČÁKOVÁ	-

Table 1: Minima timings of CzeV 270.

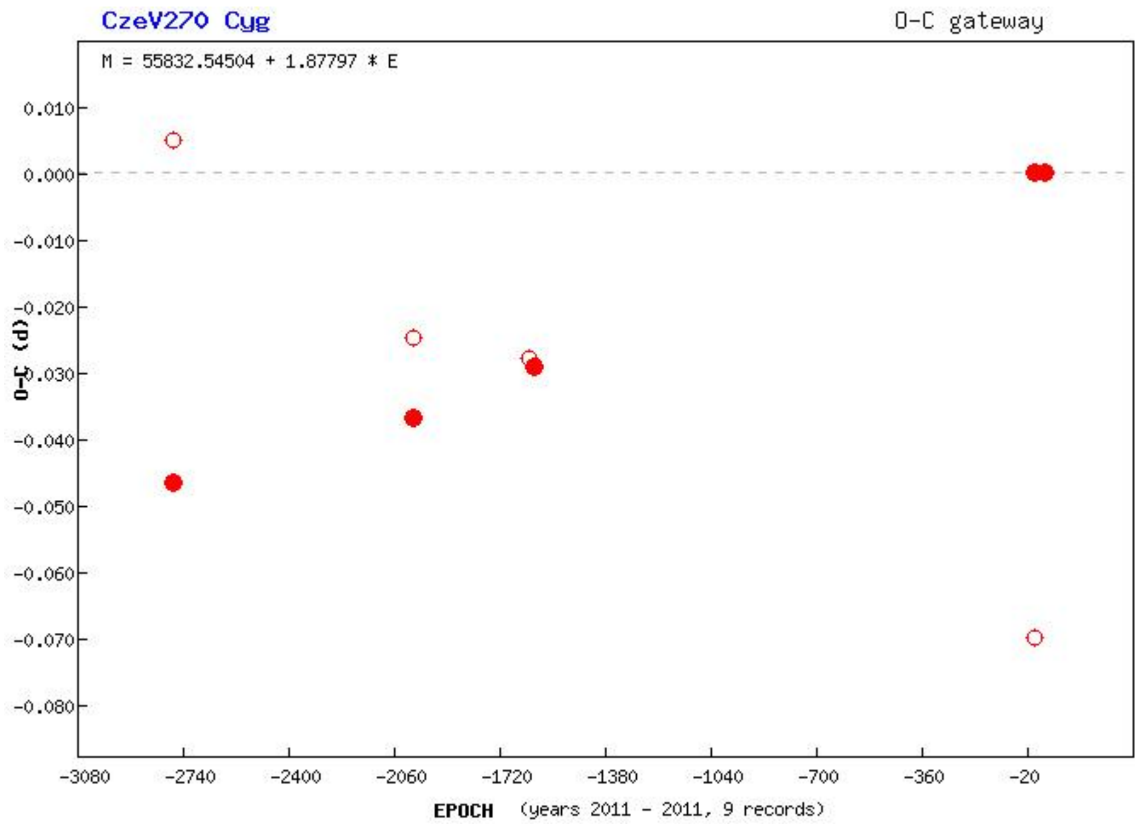

Figure 7: O-C diagram of CzeV 270. This diagram shows rapid apsidal motion of this eclipsing binary.

GSC 02712-0743 = CzeV 323 (R.A. = $21^h35^m22.00^s$ DEC. = +35°15’05.8” Equinox: 2000.0), amplitude 12.48 – 12.82 mag (V), type EW, has been independently discovered on September 27, 2011 by Radek Dřevěný from Znojmo and on October 15, 2011 by Martin Mašek from Hodkovice nad Mohelkou during the minima observations of CzeV 270. R. Dřevěný was observing with 200mm f/3.3 reflector and CCD G2-402. M. Mašek used 200mm f/5 reflector and CCD Meade DSI.

During the observation campaign which was targeted on CzeV 270, it has been observed also the CzeV 323 variable. Another observer of this variable was Hana Kučáková, who observed from Ostrava observatory using 200mm f/6 reflector and CCD SBIG ST8-XME.

New variable star has been preliminarily published in the Czech Variable Star Catalogue as CzeV 323. According to our observations, there were determined these elements: Max. = HJD 2455832.52194 + 0.429105*E.

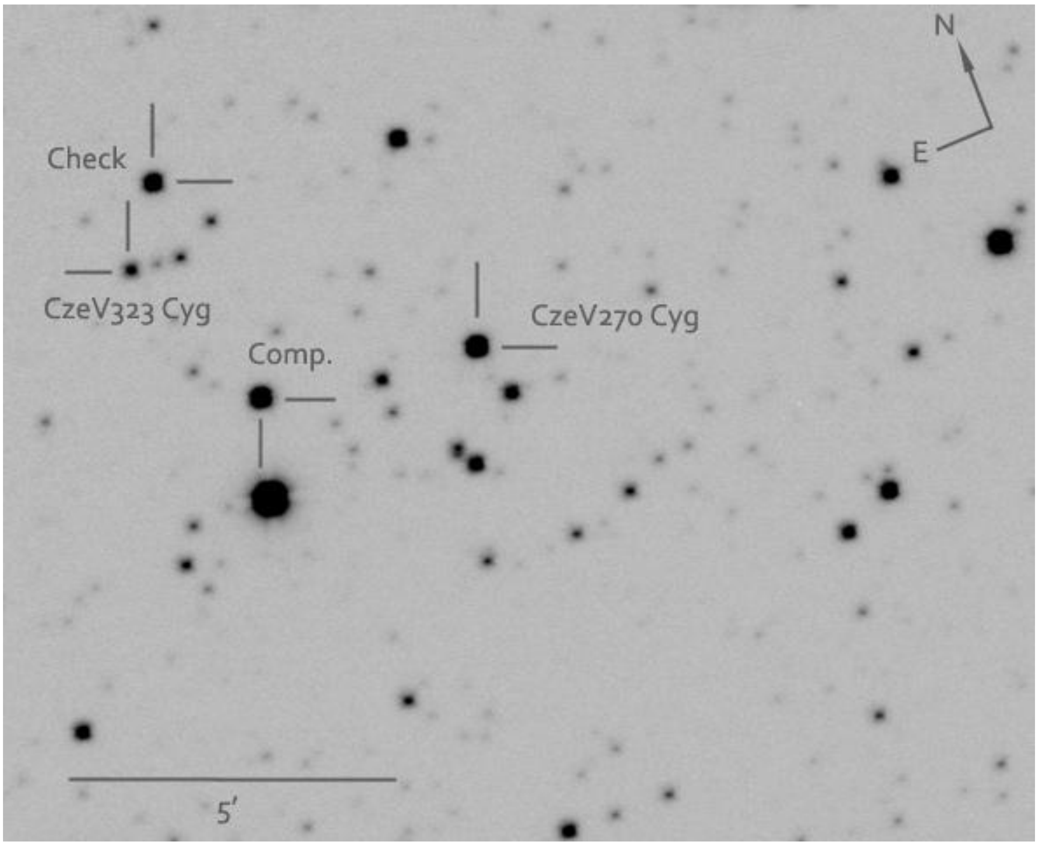

Figure 8: Finding chart for the new variable CzeV 323. Comp. = GSC 02712-00973.

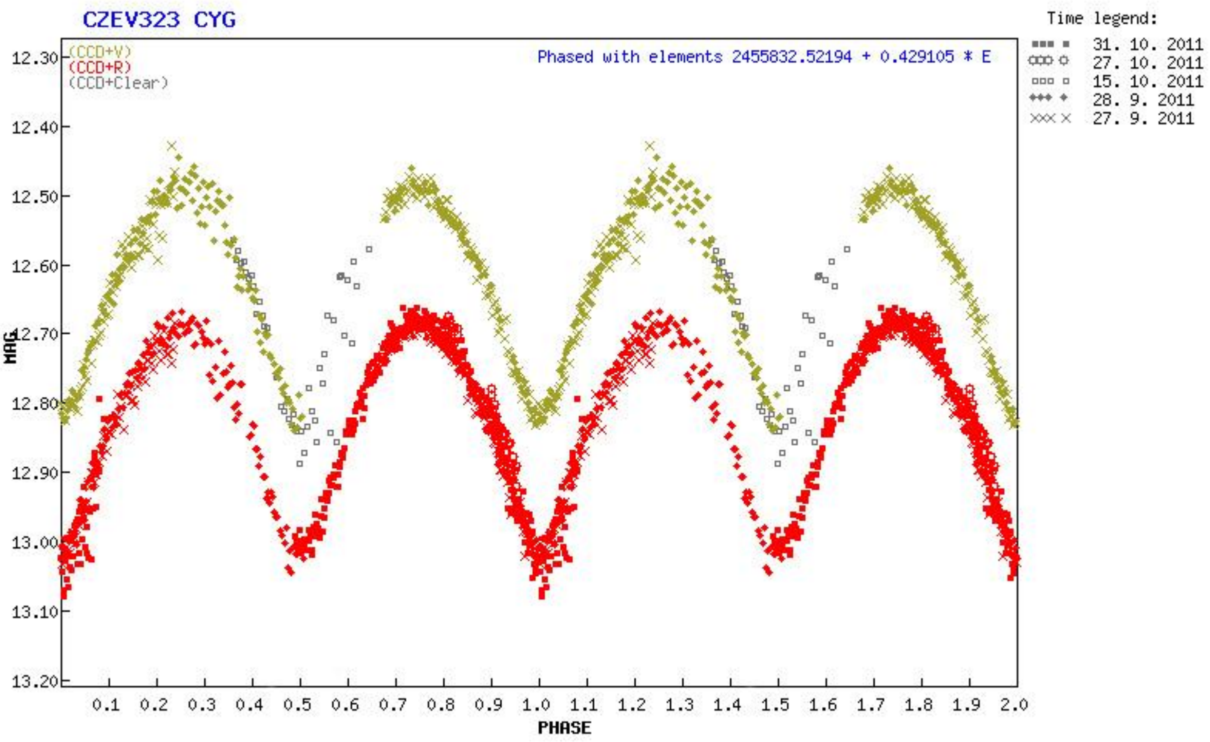

Figure 9: Phased light curve CzeV 323 in V and R photometrical filtres and clear.

Remarks

All CCD and DSLR images were reduced with program package MuniWin (Motl, 2011), times of primary and secondary minima have been determined using AVE (Barberá, 2000, method Kwee-van Woerden). Preliminary light elements were obtained by PerSea (Maciejewski, 2004, method A.Schwarzenberg–Czerny) and further refined with VarPlot (Motl, 2005).

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Pojmanski G., 2005, ASAS-3, http://www.astrouw.edu.pl/asas/

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Several Peculiar Variable Stars Discovered in Zlín

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Abstract: In 2011, more than 70 new variable stars were discovered in the town of Zlín. Several of them show lesser-known (for an amateur observer) or even peculiar characteristics and as such are presented here. The discussed variables are β Lyr stars with asymmetrical maxima, single modal HADS, a flare star (UV Cet type), fast physical variables and an eclipsing variable with pulsating overtones.

Abstrakt: V roce 2011 bylo ve Zlíně objeveno více než 70 nových proměnných hvězd. Několik z nich vykazuje méně známé (pro amatérského pozorovatele) až zvláštní charakteristiky a tyto jsou zde prezentovány. Mezi zde popisované proměnné patří hvězdy typu β Lyr s asymetrickými maximy, jednomodová HADS, flare star (typ UV Cet), rychlé fyzikální proměnné a zákrytová proměnná s pulzy.

β Lyr stars with asymmetrical maxima

More than half of our discovered stars are contact or semidetached eclipsing binaries. While most of them are almost textbook examples of their class (EW or EB), a few apparent EB binaries showed not only asymmetry in minima but in maxima as well, some to such extend that the asymmetry in maxima is by far larger than in minima. The phenomenon has been tracked down, with much appreciated help by Luboš Brát, to O'Connell effect, although other possible explanations, such as multimodal HADS, cannot be ruled out.

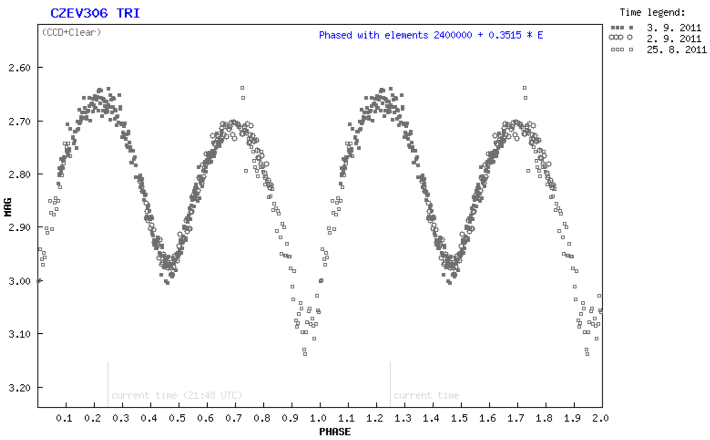


Figure 1: Example of EB with asymmetrical maxima: CzeV306 Tri.

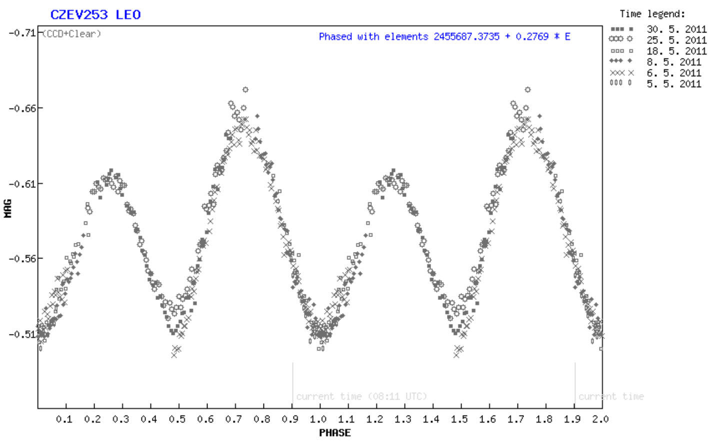
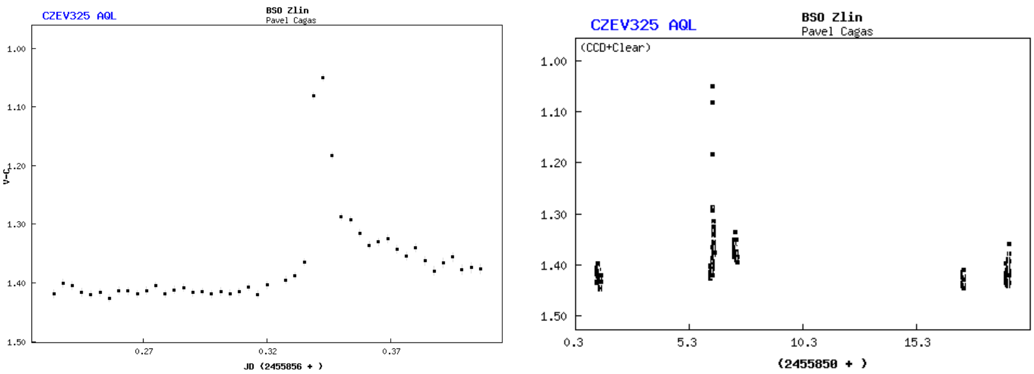


Figure 2: Example of EB with asymmetrical maxima: CzeV253 Leo.

Flare star (UV Cet type)

By a stroke of luck, one of the discovered variables is a flare star, an UV Cet type. Due to the very short duration of brightness increase (10 - 20 min) and irregularity and scarcity of the flare events, it is quite uncommon to record such event. In this case, the brightness didn't fall exactly to pre-flare levels and stayed slightly elevated for at least another 24 hours. It was only after 11 days when pre-flare levels were recorded again.

We would like to thank Ondřej Pejcha for an advice on the classification of the star.

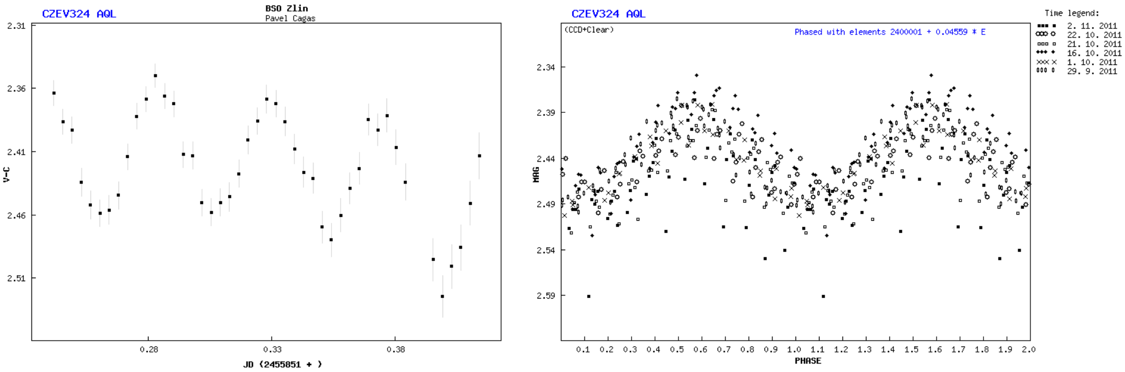


Figures 4, 5: Flare star CzeV325 Aql (main event and longer term graph).

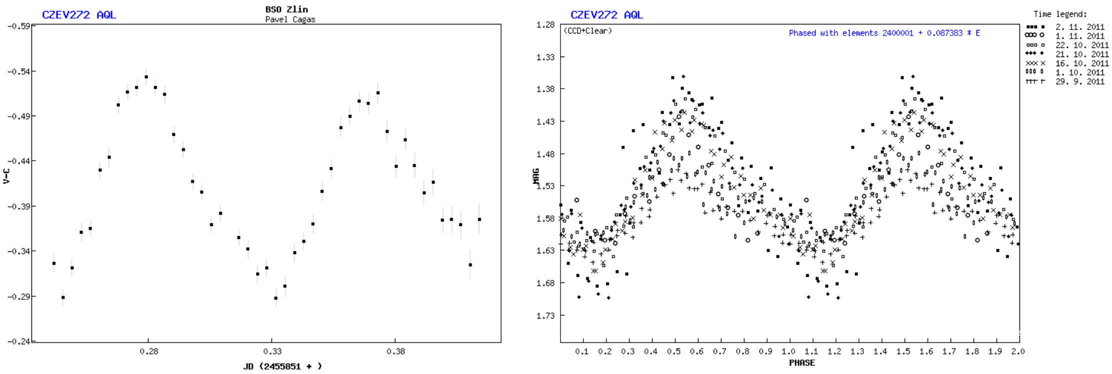
Fast physical variable

Some of the discovered stars had rather puzzling properties. Their light curve showed many fast triangular maxima, apparently a physical variable. After ruling out more common types (Cepheids, RR Lyr, DSct, cataclysmic and eruptive types), the most likely type left is SX Phoenicis. Both amplitudes and periods fits in common margins of this type (see figure captions for specific values).

Please note, that the apparent linear trend in following graph is due only to extinction.



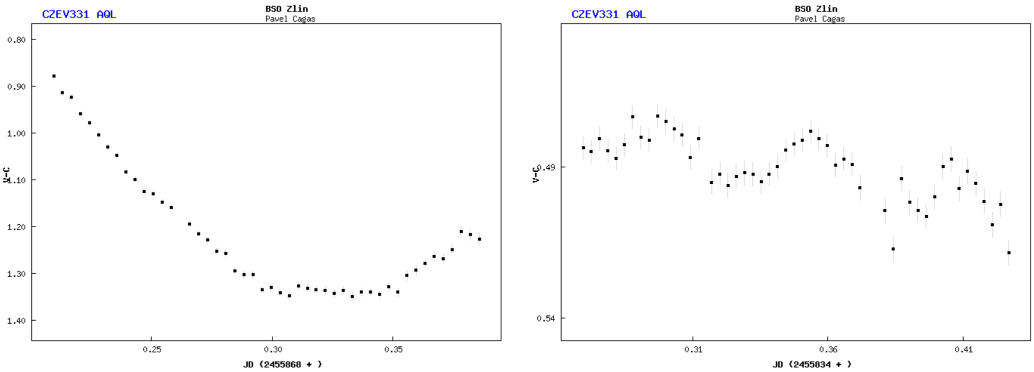
Figures 6, 7: CzeV324 Aql, light and phase curve; amplitude = 0.1 mag, P = 0.0456 d.



Figures 8, 9: CzeV272 Aql, light and phase curve; amplitude = 0.25 mag, P = 0.0874 d.

Algol type binary with variable component

CzeV331 Aql has been regarded as classical Algol type binary until short term fluctuations were found in the "constant" parts of the light curve. A working hypothesis is that one component is a variable star by itself, probably of a physical type. The amplitude of the fluctuations was found to be 30 mmag and the period is 0.055 d. A special care was taken to rule out these fluctuations as mere artifacts: none of the check stars around showed similar behavior and the fluctuations were observed for several nights in consistent manner.



Figures 10, 11: CzeV331 Aql, primary minimum and fluctuations during "constant" phase.

All presented data were obtained from two sites:

- CzeV253 Leo, CzeV325 Aql, CzeV324 Aql, CzeV272 Aql and CzeV331 Aql from BSO run by Pavel Cagaš (address given above), equipped with an Orion Newtonian telescope 10" f/5.3, CGEM mount and MII G4-16000 CCD camera (unfiltered, field cropped to 3072x3072 px).
- CzeV306 Tri and CzeV198 Sge from Hinata Observatory run by Václav Přibík (address given above), equipped with a SkyWatcher Newtonian telescope 10" f/4.7, EQ6 Pro mount and MII G2-1600 CCD camera (using Astronomik CLS filter due to high light pollution).

Data were processed using C-Munipack software package and graphs were produced using online tools at the var.astro.cz site.

Presented stars (J2000.0):

CzeV198 Sge, RA = $19^h59^m00^s.80$, DEC. = +19°00'47".2, HADS, 15.0 - 15.7, USNO-B1.0 1090-0485726

CzeV253 Leo, RA = $11^h16^m59^s.63$, DEC. = +27°23'31".5, EB, 13.4 - 13.6, GSC 1983-1931

CzeV272 Aql, RA = $19^h54^m52^s.19$, DEC. = +13°16'23".2, SX Phe, 13.4 - 13.5, GSC 1070-1640

CzeV306 Tri, RA = $02^h00^m07^s.50$, DEC. = +35°15'54".0, EB, 14.3 - 14.7, USNO-A2.0 1200-00842249

CzeV324 Aql, RA = $19^h57^m41^s.57$, DEC. = +13°02'43".7, SX Phe, 14.8 - 14.9, USNO-A2.0 0975-17294793

CzeV325 Aql, RA = $19^h53^m31^s.82$, DEC. = +13°10'19".0, UV Cet, 14.1 - 14.5, USNO-A2.0 0975-16973908

CzeV331 Aql, RA = $19^h57^m32^s.58$, DEC. = +12°54'40".6, EA, 13.8 - 14.3, GSC 1079-0706

References

Motl, D., 2009, C-Munipack Project

CzeV catalog: http://var.astro.cz/newvar.php

http://var.astro.cz/

http://en.wikipedia.org/wiki/SX_Phoenicis_variable

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Variable Stars Discovered at the Hinata Observatory

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Abstract: A report on seven new variable stars discovered: three in the CW Sge field (EW, EB and HADS), one in the V1070 Her field (EB), one in the GSC 02420-00093 (CzeV166 Aur) field (EA) and two in the RU Tri field (EB and EW). Orbital parameters and periods of presented stars have been determined.

Abstrakt: V tomto článku je prezentován objev sedmi proměnných hvězd: tři v poli CW Sge (EW, EB a HADS), jedna v poli V1070 Her (EB), jedna v poli GSC 02420-00093 (CzeV166 Aur) (EA) a dvě v poli RU Tri (EB and EW). Orbitální elementy a periody všech tšchto hvězd jsou určeny a zde uvedeny.

Since its commission in 2008, a total of 25 new variable stars have been discovered (CzeV) at the Hinata Observatory in Zlín-Malenovice, the Czech Republic. For seven of these, the orbital parameters and periods have been determined and are presented here. The stars have been catalogued in CzeV and the catalogue names are used here.

Equipment, site and process

All measurements were obtained using a 10" f/4.7 SkyWatcher Newton, an EQ6 Pro mount and MII G2-1600 CCD camera with a Astronomik CLS filter. Exposure time was 120 s, darkframe and flatfield corrected. The observation site is heavily polluted with light, with many reflexes contaminating the field.

Data has been processed using C-Munipack software package, times of minima have been estimated using Protokoly. Coordinates are given in J2000.0.

Stars presented

CzeV196 Sge

This star was discovered whilst observing CW Sge. It is located at RA = $20^h01^m10^s.04$, DEC = +19°18'47".8 and is also identified as GSC1625.1120. In GSC, its magnitude is given as 12.7 mag and the apparent amplitude is 0.4 mag.

First, a decrease of brightness with an apparent minimum was seen, with more minima and maxima during follow-up observations. The period has been estimated as 0.3795 d and the phase curve showed an EW characteristics.

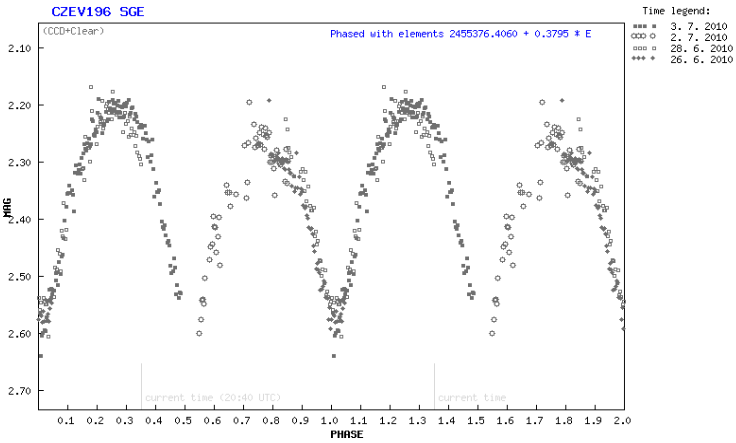

Figure 1: CzeV196 Sge.

date, time (UT)	points	filter	time of minima (HJD)
2010-06-26, 22:11 – 00:31	67	CLS	
2010-06-28, 20:15 – 00:51	111	CLS	2455376.4060 (p)
2010-06-02, 21:19 – 00:30	66	CLS	
2010-06-03, 20:06 – 00:29	125	CLS	

Table 1: Observations of CzeV196 Sge.

CzeV197 Sge

As with CzeV196 Sge, the star was discovered whilst observing CW Sge. It is located at RA = $20^h00^m57^s.40$, DEC = +19°06'55".7 and is also identified as USNO-B1.0 1091-0482496. In USNO-B1.0, its magnitude is given as 14.4 mag and the apparent amplitude is 0.3 mag.

First, an increase of brightness to maximum was seen, with more minima and maxima during follow-up observations. The period has been estimated as 0.2598 d and the phase curve showed an EB characteristics. Asymmetrical maxima suggest presence of the O'Connell effect.

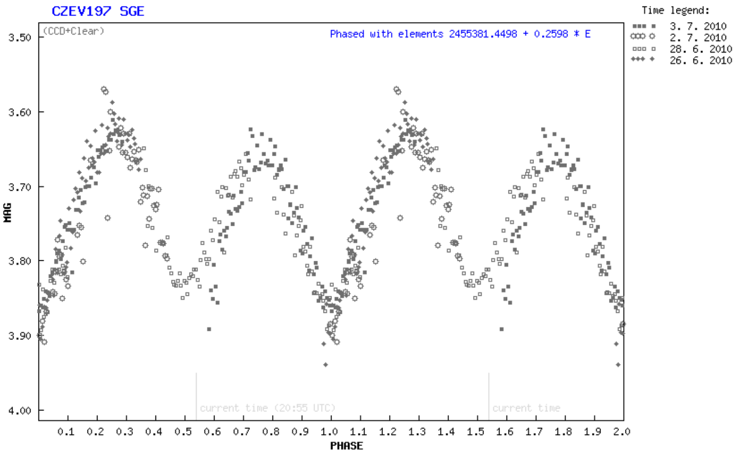

Figure 2: CzeV197 Sge.

date, time (UT)	points	filter	time of minima (HJD)
2010-06-26, 22:11 – 00:31	67	CLS	
2010-06-28, 20:15 – 00:51	109	CLS	2455376.3846 (s) 2455376.5123 (p)
2010-06-02, 21:19 – 00:30	66	CLS	
2010-06-03, 20:06 – 00:29	125	CLS	2455381.4498 (p)

Table 2: Observations of CzeV197 Sg.e

CzeV198 Sge

As with two previous stars, the star was discovered whilst observing CW Sge. It is located at RA = $19^h59^m00^s.80$, DEC = +19°00'47".2 and is also identified as USNO-B1.0 1090-0485726. In USNO-B1.0, its magnitude is given as 14.8 mag and the apparent amplitude is 0.7 mag.

In every observation, several sharp maxima and shallow minima have been seen, suggesting a physical variable star. The period has been estimated as 0.0661 d and the phase curve showed a HADS characteristics with only single pulsation mode.

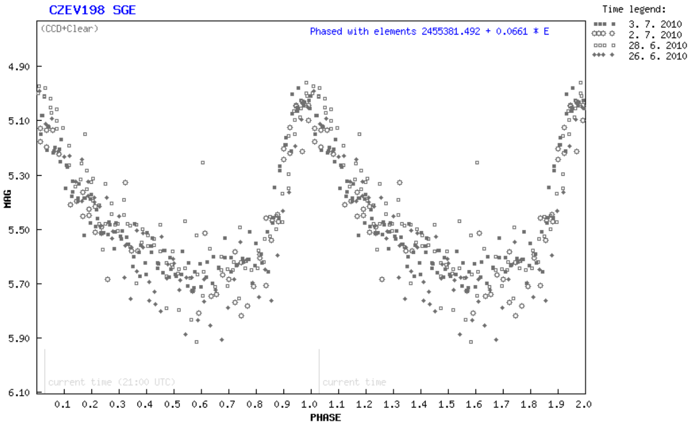

Figure 3: CzeV198 Sge.

date, time (UT)	points	filter	time of minima (HJD)
2010-06-26, 22:11 – 00:31	67	CLS	several
2010-06-28, 20:15 – 00:51	108	CLS	several
2010-06-02, 21:19 – 00:30	66	CLS	several
2010-06-03, 20:06 – 00:29	125	CLS	several

Table 3: Observations of CzeV198 Sge.

CzeV241 Her

This star was discovered whilst observing V1070 Her. It is located at RA = $17^h49^m28^s.59$s, DEC = +36°55'35".4 and is also identified as GSC 2619.590. In GSC, its magnitude is given as 13.6 mag and the apparent amplitude is 0.3 mag.

In almost every observation, a prominent primary minimum as been seen. Unfortunately, no secondary minimum could be obtained. The period has been estimated as 0.4046 d and the phase curve showed clear EB characteristics with slight maximum asymmetry.

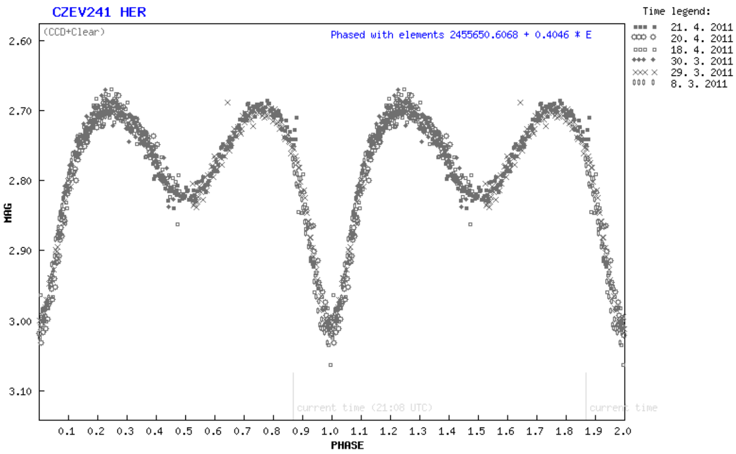

Figure 4: CzeV241 Her.

date, time (UT)	points	filter	time of minima (HJD)
2010-03-08, 00:19 – 04:22	116	CLS	2455629.5635 (p)
2010-03-29, 21:55 – 03:35	160	CLS	2455650.6068 (p)
2010-03-30, 22:39 – 02:28	95	CLS	
2010-04-18, 21:12 – 03:00	164	CLS	2455670.4313 (p)
2010-04-20, 22:12 – 02:49	116	CLS	2455672.4583 (p)
2010-04-21, 22:06 – 02:51	135	CLS	2455673.4675 (p)

Table 4: Observations of CzeV241 Her.

CzeV271 Aur

This star was discovered whilst observing CzeV166 Aur. It is located at RA = $06^h12^m40^s.07$, DEC = +31°57'24".0 and is also identified as USNO-A2.0 1200-04482857. In USNO-A2.0, its magnitude is given as 14.9 mag and the apparent amplitude is 1.2 mag.

Surprisingly this star had not been noted for a long time although the author has observed the field many times. However, the star has been easily backtracked in archive data and many primary minima have been detected. The period has been estimated as 0.88712 d and the phase curve showed clear EA characteristics with a shallow secondary minimum (which is unfortunately hidden in strong noise as the corresponding parts of light curves were just above horizon).

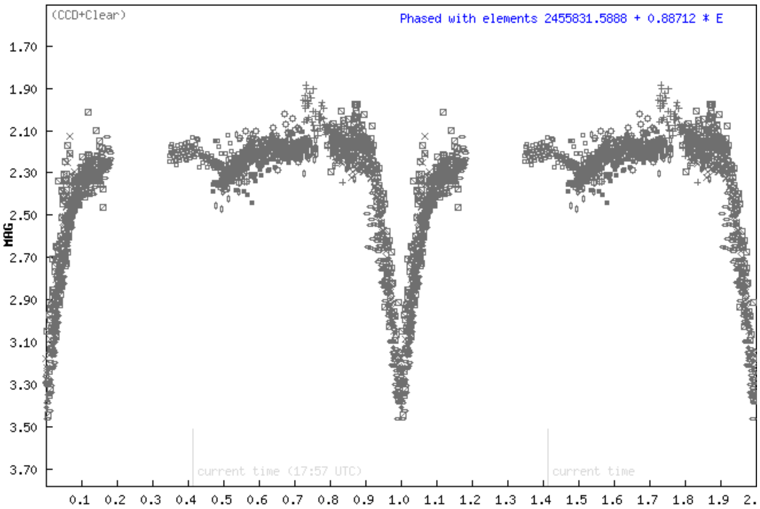

Figure 5: CzeV271 Aur.

date, time (UT)	points	filter	time of minima (HJD)
2009-09-18, 21:33 – 03:51	333	CLS	2455093.5048 (p)
2009-09-25, 20:55 – 03:52	369	CLS	2455100.6019 (p)
2009-09-26, 21:22 – 03:36	332	CLS	2455101.4894 (p)
2009-11-19, 20:33 – 00:20	205	CLS	
2010-11-14, 19:06 – 04:26	234	CLS	
2011-09-26, 22:38 – 03:51	148	CLS	2455831.5888 (p)
2011-09-27, 22:29 – 01:08	76	CLS	2455832.4774 (p)
2011-09-30, 22:41 – 03:44	143	CLS	2455835.5867 (s)
2011-10-01, 23:01 – 03:48	131	CLS	
2011-10-17, 21:48 – 03:37	162	CLS	

Table 5: Observations of CzeV271 Aur.

CzeV306 Tri

This star was discovered whilst observing RU Tri. It is located at RA = $02^h00^m07^s.5$, DEC = +35°15'54".0 and is also identified as USNO-A2.0 1200-00842249. In USNO-A2.0, its magnitude is given as 14.3 mag and the apparent amplitude is 0.3 mag.

Three similar minima have been observed. The period has been estimated as 0.3515 d and the phase curve showed EB characteristics. The first minimum is the deepest one and is the primary while the other ones are secondary. There are asymmetrical maxima and therefore again suggest presence of the O'Connell effect.

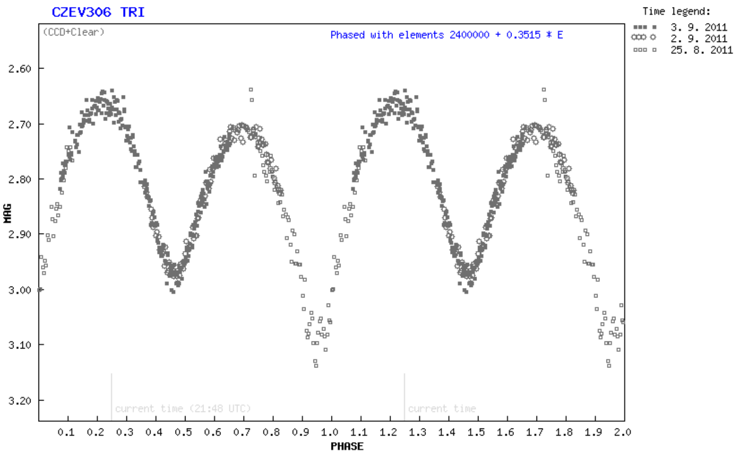

Figure 6: CzeV306 Tri

date, time (UT)	points	filter	time of minima (HJD)
2011-08-25, 23:20 – 02:36	94	CLS	2455799.5540 (p)
2011-09-02, 22:17 – 02:12	112	CLS	2455807.4690 (s)
2011-09-03, 21:09 – 02:03	255	CLS	2455808.5235 (s)

Table 6: Observations of CzeV306 Tri.

CzeV307 Tri

As with CzeV306 Tri, this star was discovered whilst observing RU Tri. It is located at RA = $01^h59^m34^s.04$s, DEC = +35°15'49".5 and is also identified as USNO-A2.0 1200-00838209. In USNO-A2.0, its magnitude is given as 14.6 mag and the apparent amplitude is 0.3 mag.

Two similar minima have been observed. The period has been estimated as 0.3571 d and the phase curve showed clear EW characteristics. Both observed minima have the same phase and has been set as primary.

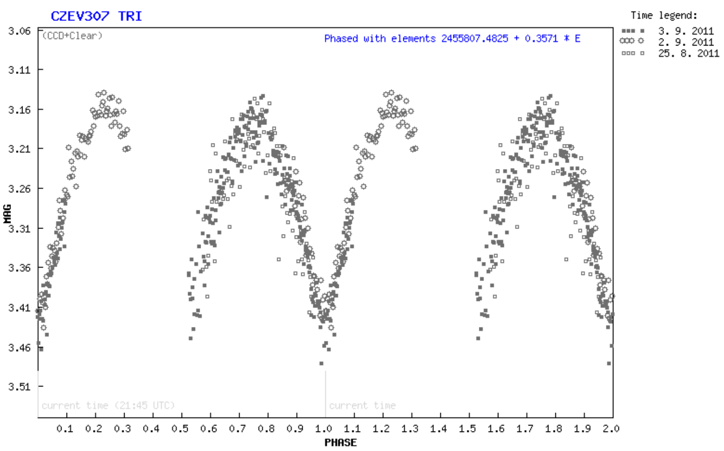

Figure 7: CzeV307 Tri.

date, time (UT)	points	filter	time of minima (HJD)
2011-08-25, 23:20 – 02:36	94	CLS	
2011-09-02, 22:17 – 02:12	112	CLS	2455807.4825 (p)
2011-09-03, 21:09 – 02:03	255	CLS	2455808.5539 (p)

Table 7: Observations of CzeV307 Tri.

Summary

star	identification	type	elements/period	magn.	ampl.
CzeV196 Sge	GSC 1625.1120	EW	2455376.4060 + E * 0.3795	12.7	0.4
CzeV197 Sge	USNO-B1.0 1091-0482496	EB	2455381.4498 + E * 0.2598	14.4	0.3
CzeV198 Sge	USNO-B1.0 1090-0485726	HADS	P = 0.0661	14.8	0.7
CzeV241 Her	GSC 2619.590	EB	2455650.6068 + E * 0.4046	13.6	0.3
CzeV271 Aur	USNO-A2.0 1200-04482857	EA	2455831.5888 + E * 0.88712	14.9	1.2
CzeV306 Tri	USNO-A2.0 1200-00842249	EB	2455799.5540 + E * 0.3515	14.3	0.4
CzeV307 Tri	USNO-A2.0 1200-00838209	EW	2455807.4825 + E * 0.3571	14.6	0.3

Table 8: Summary of presented stars.

Finding charts

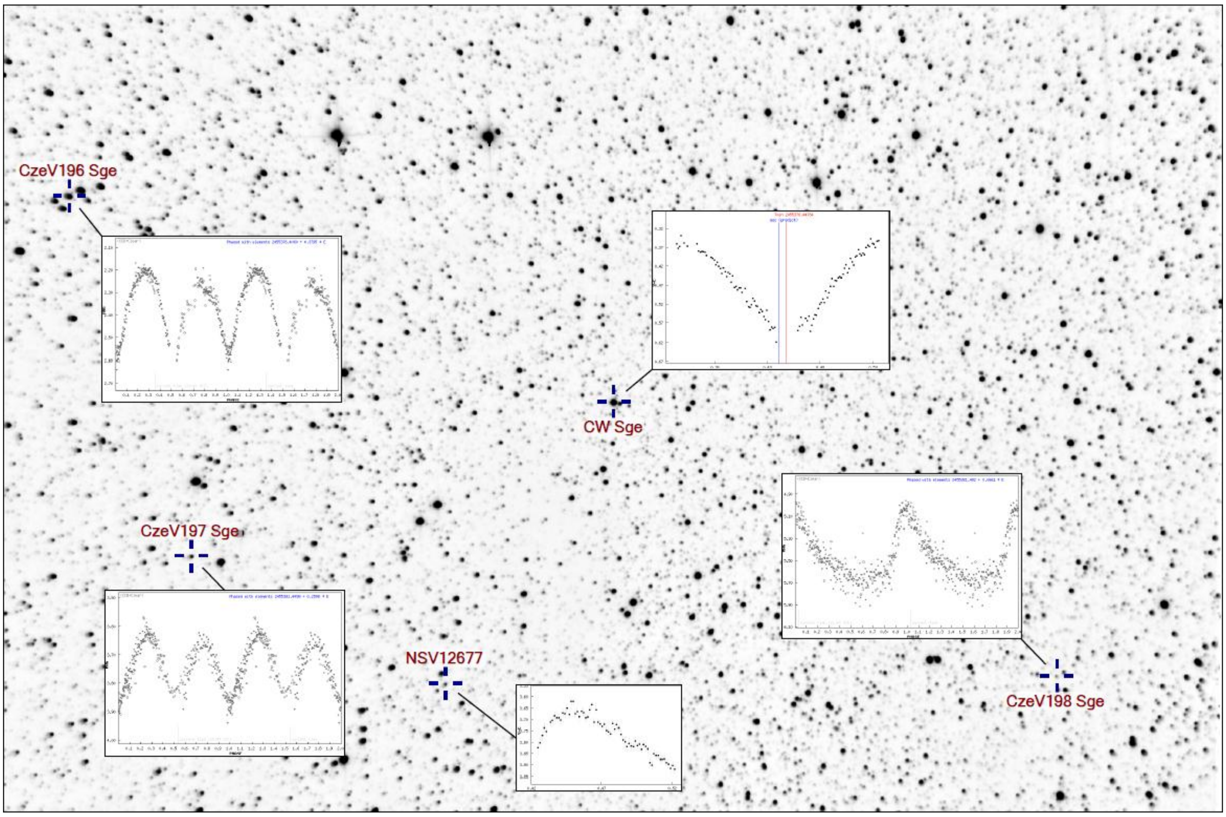

Figure 8: CzeV196, 197 and 198 Sge.

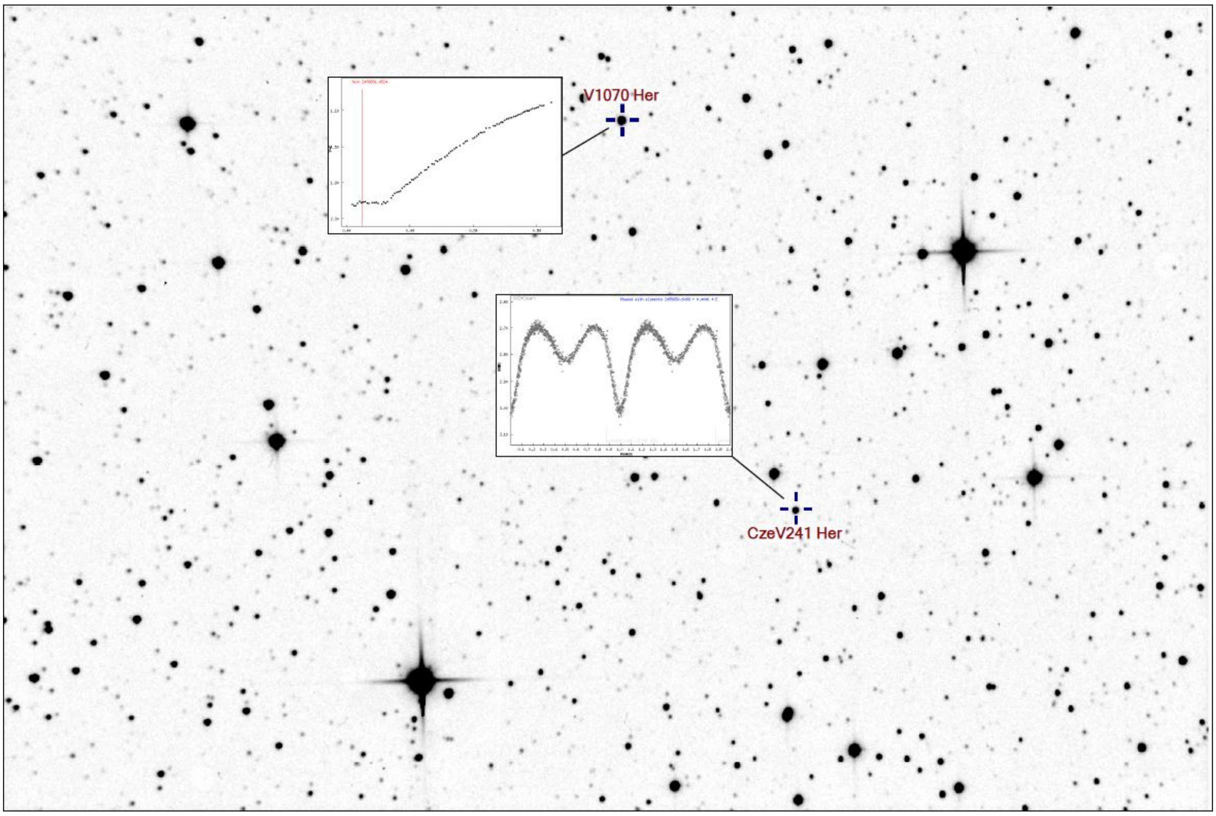

Figure 9: CzeV241 Her.

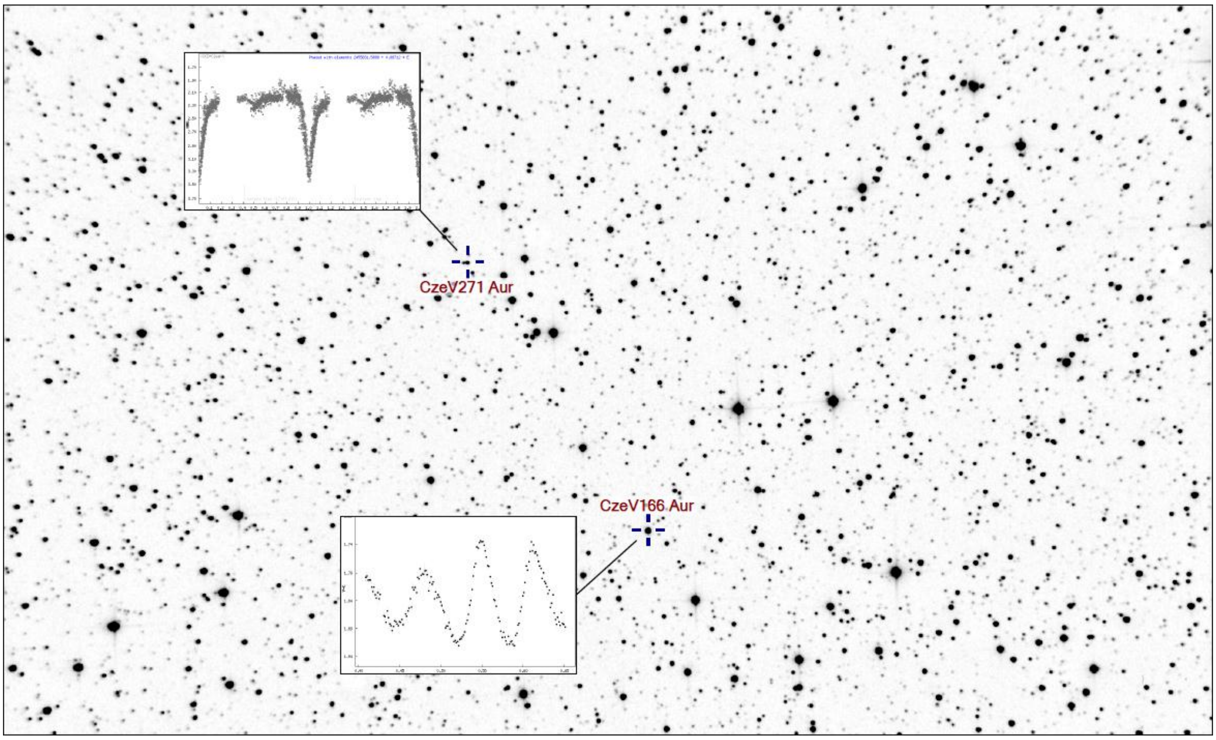

Figure 10: CzeV271 Aur.

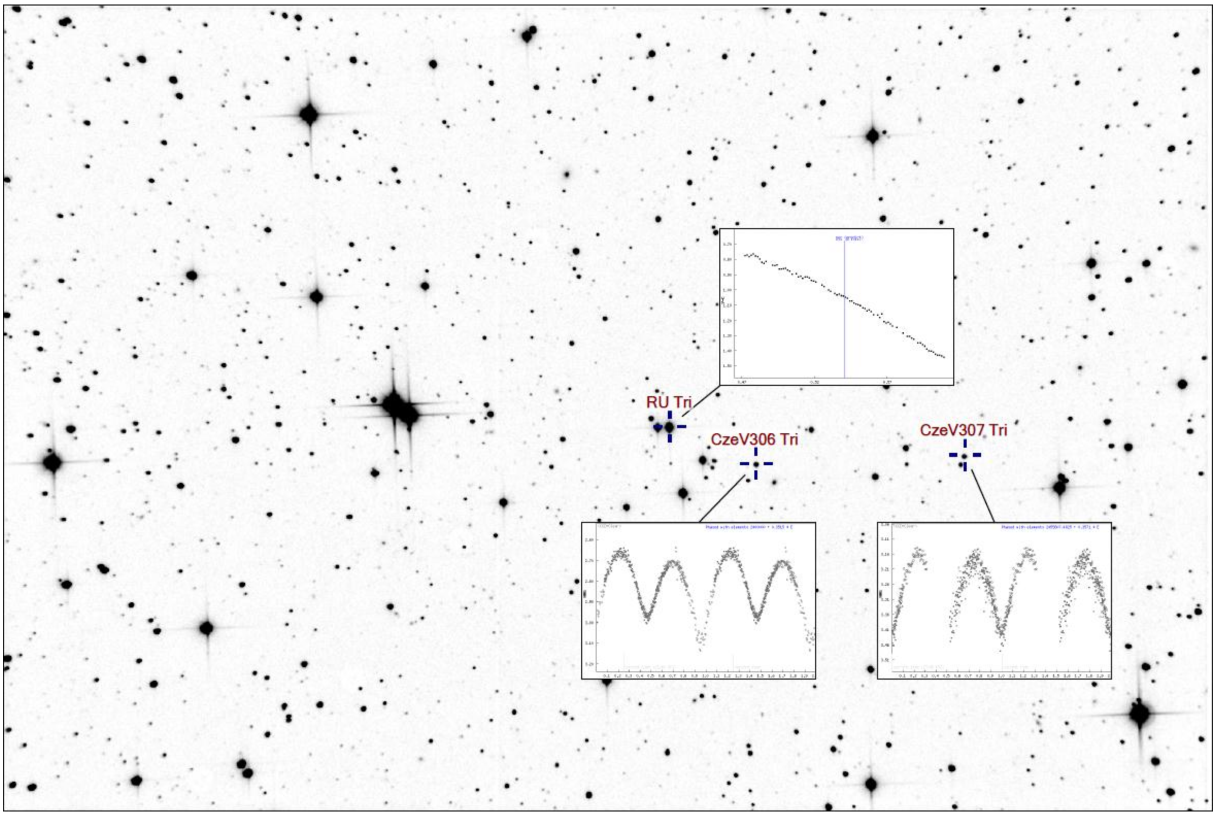

Figure 11: CzeV306 and 307 Tri.

References

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CzeV catalog: http://var.astro.cz/newvar.php

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Wide-field imaging in variable star observing

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Abstract: Acquiring wide-field frames (with respect to the diameter of the telescope) when observing variable stars results naturally in higher scientific yield considering the time spent on imaging. However, achieving both acceptable quality and sufficient S/N ratio of most of the large number of stars in the wide-field frame is usually not possible with common of-the-shelf equipment. This paper focuses on several key components of observing setup optimized for wide-field imaging. It also demonstrates the capabilities of such setup on two example fields around variable stars V1010 Her and V729 Aql.

Abstrakt: Snímání širokoúhlých snímků (vzhledem k průměru použitého dalekohledu) při pozorování proměnných hvězd přirozeně vede k vyšší vědecké hodnotě času stráveného sledováním cílového pole. Nicméně dosažení přijatelné kvality a poměru signál/šumu u dostatečně velkého množství hvězd ve velkém zorném poli není obvykle možné s běžně dostupným vybavením. Tento článek se zaměřuje na několik klíčových komponent pozorovací sestavy optimalizované pro velká zorná pole. Také ukazuje možnosti takové sestavy na dvou příkladech polí kolem proměnných hvězd V1010 Her a V729 Aql.

When discussing wide-field images, we mean properly sampled images with around 2 arc-seconds per pixel, which corresponds to the requirement of spreading of star image over at least two pixel under typical seeing conditions. Small telescopes or photographic lenses with short focal length naturally create wide-field images even on small CCD detector, but typically offer low resolution with tens of arc seconds per pixels. Also the limiting magnitude is low due to small aperture of such optics. These setups prove to be very useful for observing of already known, bright variable stars, but cannot be used for dimmer variable stars and also for dense star fields (e.g. within the Milky way) due to its inability to properly distinguish individual stars.

Typical requirement for optical setup (telescope or camera lens and CCD camera) used for variable star observing is to capture observed star and one or more comparison and check stars with good S/N ratio (bright enough to be well above background noise, but not saturated). Progress in semiconductor technology makes CCD cameras with larger detectors more affordable, so useful field of view, available even for amateur astronomers, typically contains many more stars. The probability of capturing more than one variable star within field of view during single observing session increases and with the larger field of view and dimmer stars captured, previously unknown variable stars are often discovered.

But bigger detector in the used camera does not automatically result in large usable field of view. Also other parts of the observing setup must be optimized for wide fields – telescope itself, field corrector (flattener, coma corrector etc.), focuser, telescope-to-camera adapter, filter wheel and filters etc.

Common obstacles in wide-field imaging

Quality of amateur astronomers' observing equipment, often limited to commercially available components, significantly increased in recent years. Adherence to standards and de-facto standards of individual vendors' product lines brings mutual interchangeability of various optical, electronic and mechanical components on the one side, but also limits their certain capabilities on the other side. Field of view is often limited by widely used “two-inches” standard, primarily created for attaching eyepieces to the telescope. Two inches (50.8 mm) of inner diameter of absolute majority of commercial telescope focusers results to maximal non-vignetting focal plane field diameter around 40 mm (depending on the focuser tube length, camera mechanical construction, f/ratio of the used optics and other factors). This is suitable for square detector up to 27×27 mm (~38 mm diagonal), but corners of so-called “full frame” detector of 24×36 mm area (~43 mm diagonal) suffer vignetting. It is highly recommended to choose telescope equipped with larger than two inches focuser for wide-field imaging with large-detector CCD cameras.

Wide-field optimized telescopes

No simple telescope design, available for amateur astronomer, provides good quality field of view with 40 or 50 mm diameter. It is always necessary to add correcting optical element, regardless whether refracting or reflecting telescope is used.

There are commercially available telescope setups, optimized for wide field imaging with up to 50 mm diagonal detector. Correcting elements are already built-in by the telescope manufacturer in such cases.

Refracting telescopes

For small apertures, commercial refracting telescopes span over wider range in both price and corresponding image quality. While simple and cheap achromatic refractors barely provide enough quality to be used for imaging even with small detector CCD camera, more expensive ED doublets (semi-APO) or triplet apochromatic (APO) refractors offer good image quality over wide field of view. With the exception of top quality and expensive refractors (with objective containing four or more lenses), even apochromatic refractor are rarely designed to be used with CCD detector with 20 mm or larger diagonal dimension.

To eliminate field curvature and enlarge useful refractor field of view, number of so-called field-flatteners are commercially available. Some companies offer field-flatteners specifically designed for the particular telescope. Relatively cheap ED doublets with corresponding field-flatteners can be very well used with "APS-C" (approx. 23×18 mm) or "4/3" (approx. 18×13 mm) detector formats (up to 30 mm diagonal) to achieve wide field of view. More expensive refractors with larger than two-inch focusers and field flatteners/correctors can create useful field of view with diameter up to 50 mm.

However, input aperture of common refractors is limited to approx. 80 to 120 mm range and focal lengths often span between 400 to 800 mm.

CCD type	Pixel size	Pixels resolution	Detector dimensions	arcsec/pixel 400 mm f.l.	arcsec/pixel 800 mm f.l.	Field of view 400 mm f.l.	Field of view 800 mm f.l.
KAF-1603	9.0 μm	1536 × 1024	13.82 × 9.22 mm	4.64	2.32	0.99° × 0.66°	1.98° × 1.32°
KAF-8300	5.4 μm	3358 × 2536	18.13 × 13.69 mm	2.78	1.39	1.30° × 0.98°	2.60° × 1.96°

Table 1: Image sampling and field of view of two most often used amateur CCD detectors for telescopes with 400 mm and 800 mm focal length.

Obviously refracting telescopes are suitable for cameras equipped with CCD detectors with small pixels (around 5 mm). Even for such detectors, refractors with large aperture and longer focal length are suitable for dense star fields and dim stars.

Reflecting telescopes

Reflectors typically offer larger input aperture for the same price compared to refractors. Especially Newtonian telescopes offer large light gathering power relative to their price. However, Newtonian telescopes suffer from coma – very prominent optical aberration, distorting image in distance from optical axis. Common 250 mm (10 inch), f/4.5 Newtonian telescope, often used by amateur astronomers, is capable to create only around 10 to 15 mm diameter field of view with coma aberration comparable to star image distortions caused by seeing, less than perfect tracking and other effects. So coma affects star images close to edge of very basic KAF-1603 CCD detector when used with above mentioned telescope.

Richey-Chretien (RC) is the best telescope design to create large field of view of all reflectors. RC telescopes are modified Cassegrain telescopes, replacing the parabolic primary and hyperbolic secondary mirrors with both hyperbolic mirrors (the secondary one is over-corrected relative to Cassegrain secondary mirror). Because creating of large concave hyperbolic mirror is expensive, RC telescopes tend to be the most expensive reflectors available. However, even the typical RC telescope cannot be used with CCD detectors with 40 or 50 mm diagonal dimension without suffering of aberrations on the edges of the frame due to focal plane curvature. Field-flattener refracting optical element is necessary either way. The necessity to use refracting element even on RC telescope lead to so-called Modified Dall-Kircham (MDK) design. Dall-Kircham (DK) telescopes is another Cassegrain modification with spherical secondary and elliptical primary mirrors. Spherical convex secondary mirror is much easier to manufacture so DK telescopes are cheaper then RC ones. While RC modification enlarges field of view compared to classical Cassegrain, DK design narrows it. But it is possible to design refracting field corrector (which has to be present also in RC telescope either way) to lower inherent DK aberrations and to create large (up to 50 mm diameter) field of view. Numbers of MDK telescopes are available of-the-shelf for amateurs. Unfortunately companies offering these telescopes do not reflect the fact that DK is cheaper to manufacture compared to RC and MDK telescopes belong to most expensive ones together with RC designs.

Cassegrain reflector modifications offer larger f-ratios compared to Newtonian telescopes. Fastest RC or MDK telescopes offer f-ratio around 6.5 or 7 and naturally have longer focal length compared to wide-field Newtonian telescopes with f/3.5 or f/4 mirrors of the same diameter. Longer focal length results into narrower field of view.

When taking into account the fact, that all wide-field reflecting telescopes, capable to create up to 50 mm field of view, consist of primary and secondary mirrors and refracting corrector element, Newtonian telescopes with fast primary mirror, large-enough secondary mirror, proper large-diameter focuser and quality coma corrector offer the best capabilities for wide-field imaging for the less money compared to other designs.

Coma correctors

Numerous coma correctors are available of-the-shelf for amateur astronomers using Newtonian telescopes. Vast majority of them are limited to two inches standard, so they are suitable for up to APS-C or 4/3 CCD formats. Special designs of correctors with large output optical elements are available even for two inches standard to be used with full-frame 36×24 mm detectors. But it is necessary to count with vignetting when such large detectors are used.

There are coma correctors of numerous optical designs available. Similarly to other optical designs, individual correctors differ in the ability to eliminate coma aberration far from the optical axis, in the amount of chroma aberration naturally introduced by any refracting elements etc. Simple doublet coma correctors like Baader MPCC are suitable for small detectors up to 20 mm diagonal. Currently top of the class coma corrector design is Paracorr by TeleVue, consisting of four elements in two groups.

Let us note numerous coma corrector designs affect resulting focal length of the optical setups. For instance Paracorr coma corrector prolongs focal length of the telescope by factor 1.14.

Currently only "Wynne" three lenses coma corrector design is available with three inches diameter, suitable for 50 mm diagonal detectors. Unfortunately for amateur astronomer, the price of three inches Wynne correctors is often higher than the price of the rest of observing setup including telescope and mount.

Coma correctors introduce some unwanted effects, which must be taken into account when used for wide field variable star observing. The first effect is field distortion.

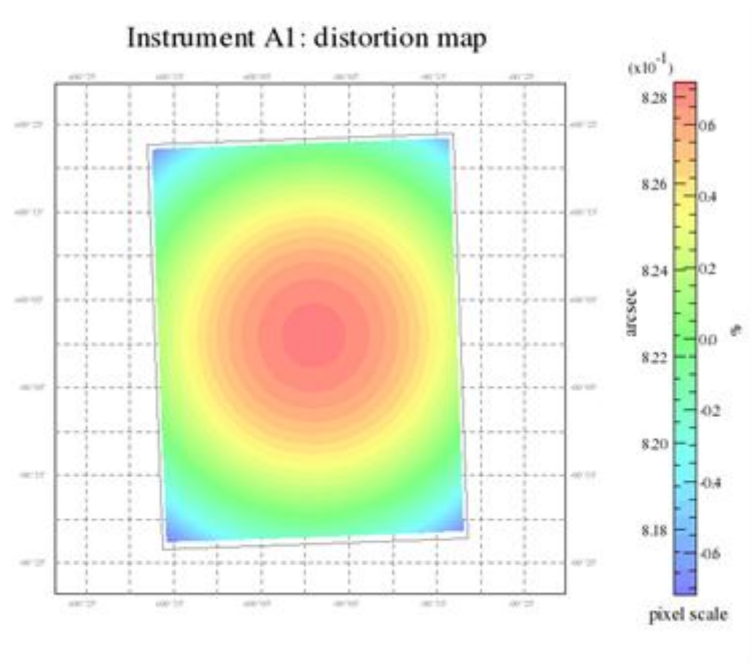

Figure 1: Distortion map of the KAF-8300 CCD detector (13×18 mm) frame on 250 mm, f/4.8 Newtonian telescope with Paracorr coma corrector. Resulting focal ratio is f/5.4 due to focal length prolonged by Paracorr coma corrector. Distortion map created using SExtractor software package by V. Přibík.

Image field distortion does not negatively affect photometry measurements themselves, but causes significant problems for frame astrometric reduction. While astrometric reduction is not in principle necessary for variable star observing, it can be used by software packages to streamline data processing. Software must include higher-order transformations between plate coordinates and tangentially projected celestial coordinates beside the scaling, translation and rotation.

Another unwanted effect directly affecting photometric precision of images acquired with coma correctors are reflexes. Reflexes in image depend on the corrector optical design as well as on the reflexivity of CCD detector cover glass (if present), CCD detector itself etc. Especially Wynne corrector design is known for of diffuse reflections of bright stars in the field, but also other designs suffer from the same problem.

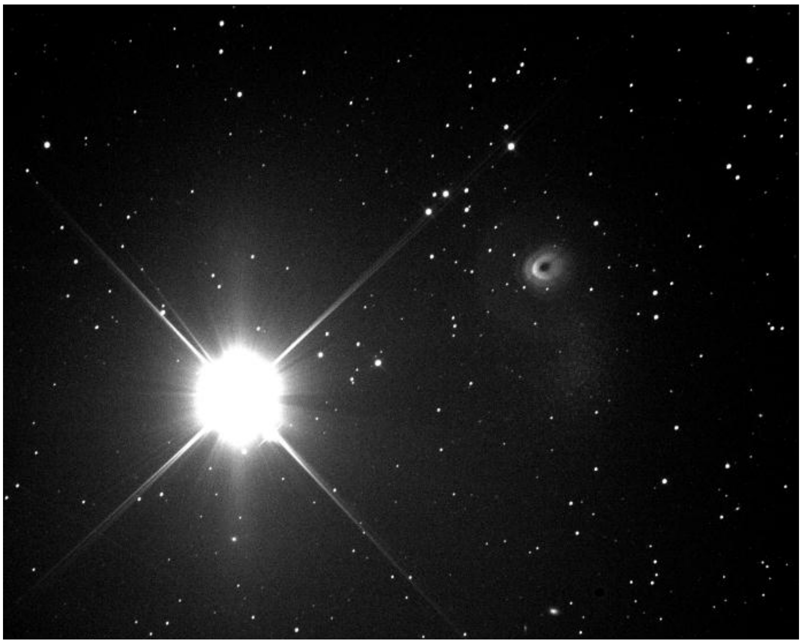

Figure 2: Example reflex image created by Paracorr coma corrector on 250 mm, f/4.8 Newtonian telescope. Reflex is center-symmetrical image of bright star Regulus, just above “Leo 1” dwarf galaxy.

Reflexes typically do not affect photometric precision in majority of fields without very bright star(s), their intensity is well below the image background noise. If some bright star in the field of vied is unavoidable, its reflex image must be taken into account when planning and processing observations to keep target, comparison and check stars out of reflex image. Proper guiding is then important to keep the bright star (and then also its reflex) on the same area of the detector not to introduce artifacts into light curve.

Vignetting

Vignetting (irregular illumination of the field of view, typically more illuminated center and less illuminated edges) is inherent feature of almost all optical systems. Vignetting is caused by many factors, depending on the optical system used. Telescope tubes, light baffles, focusers, filter wheels and filters, camera housing and telescope adapters can cause vignetting in certain circumstances. Very important cause of vignetting on the Newtonian telescopes is secondary mirror – small secondary mirror reflects only portion of the the light cone to border portions of the detector while large secondary mirror of wide field setups block substantial part of the incoming light.

As opposite to reflexions, vignetting can be properly calibrated using flat fields. Applying flat fields is highly recommended to reduce influence of dust particles on filters and other optical surfaces close to CCD detector either way. Proper guiding is again very important to keep the location of such traces on the same portions of the CCD. Dust particle trace, falling to variable or comparison star image, causes constant offset but does not affect the light curve shape itself if it does not move over the detector among individual exposures.

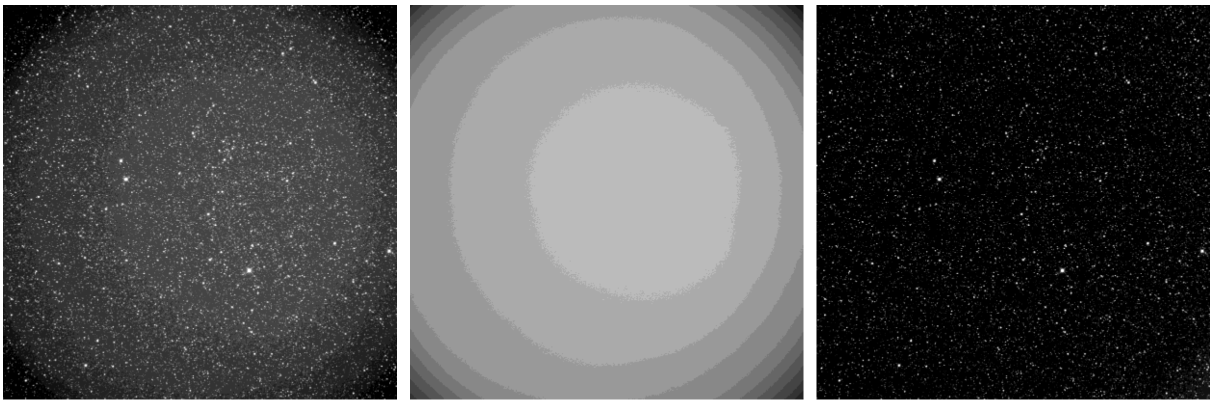

Figure 3: Example of vignetting on 71'×71' wide field of view imaged by 250 mm, f/5.4 Newtonian telescope with 2-inch Paracorr coma corrector (actual field of view dimensions are 27×27 mm). Raw frame (left), flat field frame (center) and resulting flat-field corrected image (right).

Darkening of image border regions corrected by flat field frame does not directly influence photometry precision with the exception of S/N ratio. Applying flat field effectively means amplifying of the signal proportionally to its darkening. But amplifying of weak signal to the level of strong signal amplifies not only the signal itself, but also system read noise, dark current noise etc., so the S/N ratio decreases.

Amount of vignetting over the detector area can be checked by acquiring of rich star field with camera out of focus, as illustrated as Figure 4.

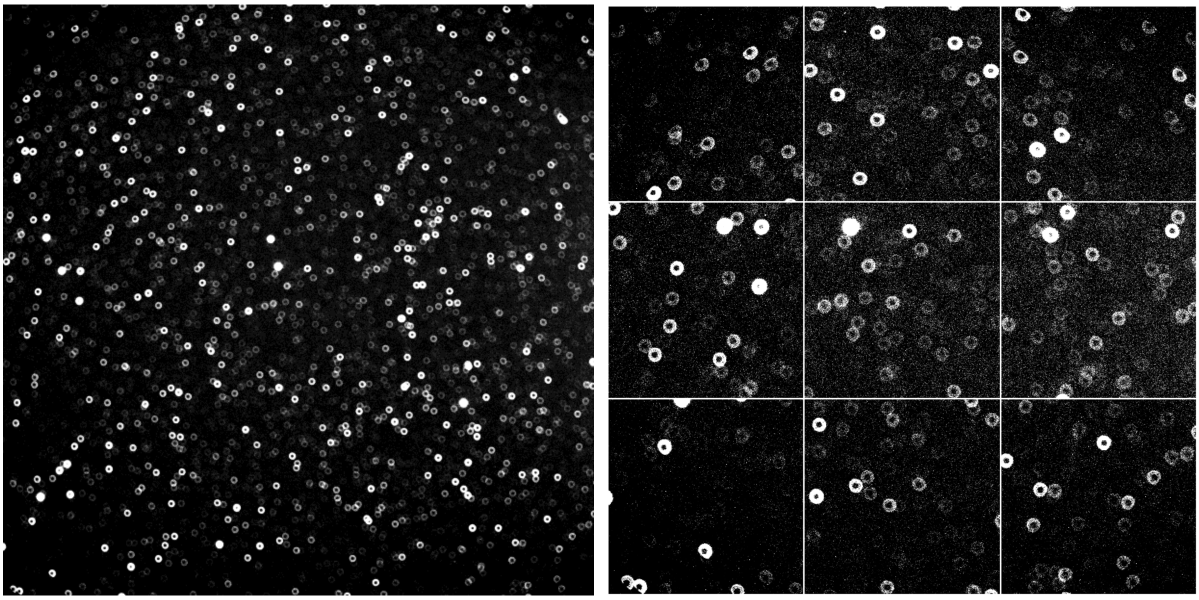

Figure 4: Out of focus 3072×3072 pixels image demonstrates amount of vignetting (left). Nine enlarged 256×256 pixels crop portions show the shape of input "aperture", used to create image in image corners, center of edges and image center. Pixels close to image center axes are illuminated by almost complete input aperture, but almost a third of the input aperture area is cut for pixels in image very corners.

Large detector CCD cameras

Cooled, slow-scan CCD cameras with large detectors up to 36×36 mm are readily available. The largest available detectors are equipped with anti-blooming gate (ABG), which is considered unsuitable for scientific applications due to non-linear response. However, both laboratory measurements with constant light source and real experience with variable star and exoplanet transit measurements show that CCD detectors with blooming protection around 100× saturation level provide response with linearity comparable with non-ABG CCD detectors over the majority of its dynamic range. Detectors with blooming protection around 1000× saturation level show non-linear response in the upper half of the dynamic range.

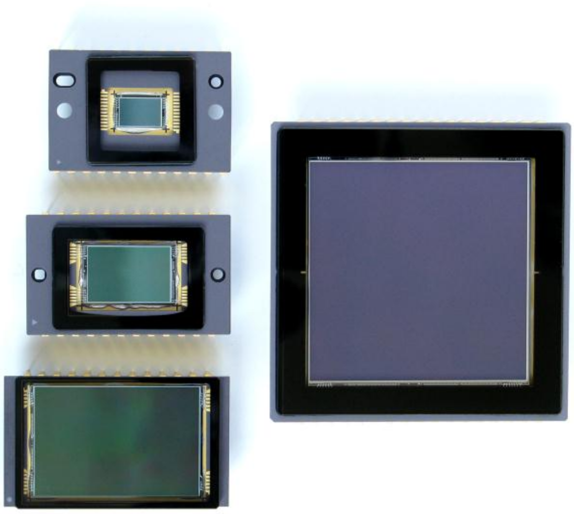

Figure 5: Comparison of most commonly used CCD detectors used for variable star observations by amateur astronomers: KAF-0402 (top left), KAF-1603 (center left), KAF-6303 (bottom left) and KAF-16803 (right).

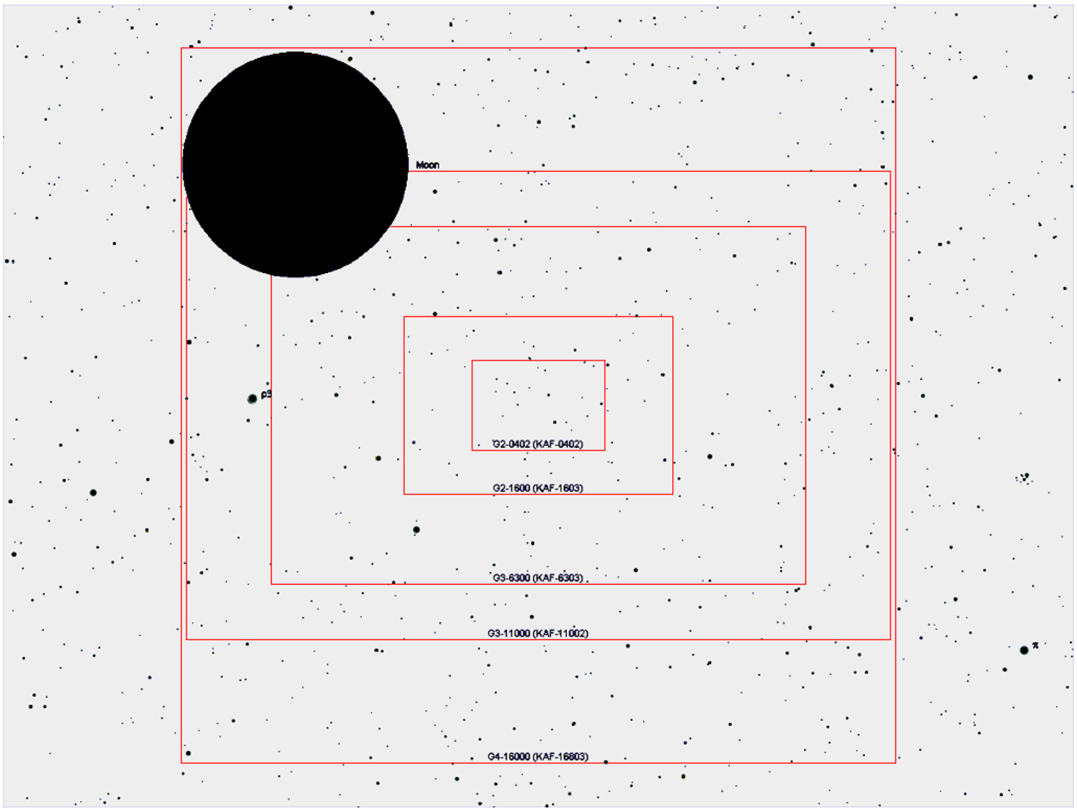

Figure 6: Comparison of field of view of various CCD cameras with a size of Moon.

CCD	W [px]	D [px]	Px [μm]	W [mm]	D [mm]	arcsec/ px	FOV x [°]	FOV y [°]
KAF-0402	768	512	9	6,91	4,61	1,39	0,30	0,20
KAF-1603	1536	1024	9	13,82	9,22	1,39	0,59	0,39
KAF-6303	3072	2048	9	27,65	18,43	1,39	1,18	0,79
KAI-11002	4032	2688	9	36,29	24,19	1,39	1,55	1,03
KAF-16803	4096	4096	9	36,86	36,86	1,39	1,58	1,58

Table 2: Field of view for CCD cameras with different detectors on telescope with 134 cm focal length.

Also other factors must be considered when choosing the CCD camera for variable star observing beside the capability of the used optics to properly create image over the detector area (and camera price, of course). Large detectors need longer time to download with the same electronics. E.g. downloading of full 16 MPx image from KAF-16803 equipped camera may take several tens of seconds, which could be comparable to exposure time itself. For short exposures, such large detectors substantially limit sampling frequency.

Large images also need lot of disk space (compare 32 MB single image from KAF-16803 to approx. 0,8 MB image from KAF-0402 based camera), takes proportionally longer to process by software etc.

Example of capabilities of wide field Newtonian telescope used for variable star observing

Commercial Orion SPX 250 mm f/4.8 (1200 mm focal length) optical telescope assembly on the Celestron CGEM German equatorial mount is used by the author to observe variable stars. The telescope is modified to enhance its capability to capture wide field images as well as to overcome its weaknesses caused by less-than-optimal design and manufacturing. First, the standard 63 mm secondary mirror was replaced with larger 75 mm one to illuminate larger field of view with less vignetting. Robust low-profile Baader Steeltrack Crayford-style focuser is used instead of the original one to support heavy cameras with large detectors. TeleVue Paracorr PSB-1100, a special variant of coma corrector designed for full-frame cameras, is used. Both focuser and coma corrector are designed to fit two-inches standard, so the resulting non-vignetting field of view diameter is only 25 mm. This is why the full 4096×4096 pixels resolution (37×37 mm) of the used G4-16000 camera is cropped to 3072×3072 pixels (27×27 mm) sub-frame by camera driver. Still the corners of the cropped area suffer significant vignetting, which limits S/N ratio. Even with all above mentioned limitations the described telescope and camera is capable to capture 9 MPx frames spanning 71×71 arc minutes with 1,39 arc second per pixel. Depending on the atmospheric conditions, majority of stars images have around 3 pixels FWHM over the field of view with 18+ mag stars with three sigma acquired with 180 s long single exposure. Bright star images naturally span wider PSF.

Capabilities of the setup were tested on the variable star V1010 Her. The 22 variable stars with the field of view identified during the first observing night, from which two were registered in GCVS or VSX database, remaining 20 variable stare were apparently unknown. Only in the case of 13 stars actual minimum was observed, so these stars were registered in CzeV catalog. Other discovered variable stars registration was postponed until subsequent observations confirm its variability.

Another field of view were chosen around the variable star V729 Aql. 44 previously unknown variable stars or suspected variable stars beside the V729 Aql itself were detected within the field of view. 32 of them were registered in CzeV catalog, because their minima were observed several times within following 10 observing nights of the field.

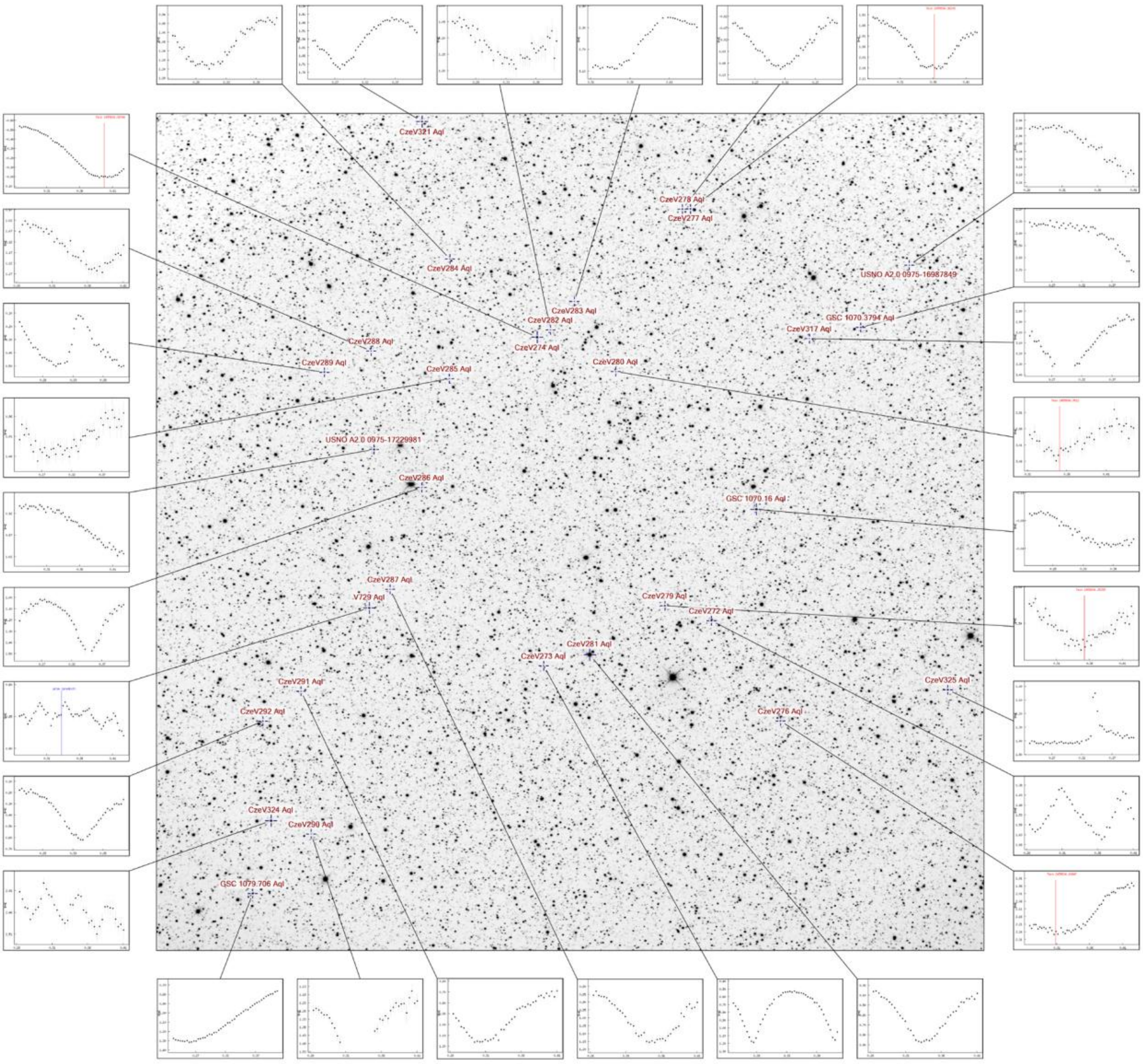

Figure 7: Illustration of the field of view around V729 Aql with 29 newly discovered stars illustrated. The light curves are added just to illustrate particular star's variability, curves themselves they span different time interval and are acquired during different nights. Image assembled by V. Přibík.

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Motl, D., 2009, C-Munipack Project

AAVSO VSX variable star database, http://www.aavso.org/vsx/

Variable Star and Exoplanet Section of Czech Astronomical Society portal, http://var2.astro.cz/EN/