BAV Journal

2016 No. 1 ISSN 2366-6706

Bundesdeutsche Arbeitsgemeinschaft für Veränderliche Sterne e.V.

http://bav-astro.de

Light curve and period of the Blazhko RRc star GSC 03529-02286 and GSC 2.3 N0ZY002187, a new variable in the field

Rainer Gröbel

E-Mail: rainer.groebel@web.de

January 2016

Abstract: *By analysis of SWASP and CRTS data, Bernhard et al. (2013) have recently shown that GSC 03529-02286 (18 14 48.187 +47 10 03.12, J2000) is an RRc type variable showing indications of Blazhko effect. A night by night reanalysis of SWASP data yielded 70 maxima and 73 minima times which revealed a Blazhko period P_B = 20.26 d. CCD observations on 13 nights in August 2013 yielded another 11 maxima and 4 minima times, covering a little more than one Blazhko cycle. It could be shown that the secondary period prevails until now. The ephemeris for the maxima could be improved to*

HJD (Max.) = 2456495.4317(37) + 0.27719643(46) d x E.

The CCD observations also revealed a short period eclipsing variable in the vicinity (GSC2.3 N0ZY002187; 18 14 26.76 +47 19 09.38, J2000) showing shallow 0.15 mag. deep eclipses with the ephemeris HJD (Min.) = 2456493.3980(6) + 0.340055(12) x E.

1. GSC 03529-02286 (18 14 48.187 + 47 10 03.12), 2MASS 18144819+4710031

In BAV Rundbrief 3/2013, Bernhard, Sdroc and Hümmerich [1] presented three new RR Lyrae stars, which had been discovered by analysis of data from the SuperWASP Public Archive [2] and Data Release 2 (CSDR2) of the Catalina Sky Survey [3]. One of them, GSC 03529-02286, stands out for its light curve (LC), which shows indications of Blazhko effect. Being favourably situated at the common boundary of the constellations Lyra, Hercules and Draco, the star was included in the observation program. Prior to the beginning of the observing season, SWASP data were reanalysed with the method outlined in [4].

1.1. SWASP data analysis

SWASP data consists mainly of two densely sampled time series won through the cameras labelled 1.03 and 1.44 with 4,109 and 8,049 measurements, respectively. The earliest series taken through camera 1.03 lasts from 2004-05-13 to 2004-09-29. The 1.44 camera series splits in two parts, first from 2007-07-15 to 2007-09-29 and from 2008-04-23 to 2008-08-09 with 1751 and 6298 points, respectively. The times of 70 maxima (max.) and 73 minima (min.) and their instrumental magnitudes could be derived.

Fig. 1 illustrates the measurements of camera 1.44 reduced with the ephemeris (1) shown in section 1.2. The LC apparently exhibits a broad, double-humped max. However, the double hump is only caused by the phase shifting of the max. during the Blazhko cycle. The arrows mark the slightly different heights of the max., indicating the limits of the phase shifting. The timings of the max. and min. were analysed with a period search program. In both cases, a neat frequency peak was present at a secondary period of 20.26 d.

Fig. 2 illustrates that the times of the extrema vary regularly against the timings given by the ephemeris, occurring between half an hour before and half an hour after the calculated times.

From the SWASP observations of 2004 until now, the Blazhko period seems to have remained essentially constant. The min. timings also follow the cycle in phase with the max., indicating that the steepness of the rising branch in the LCs remains constant.

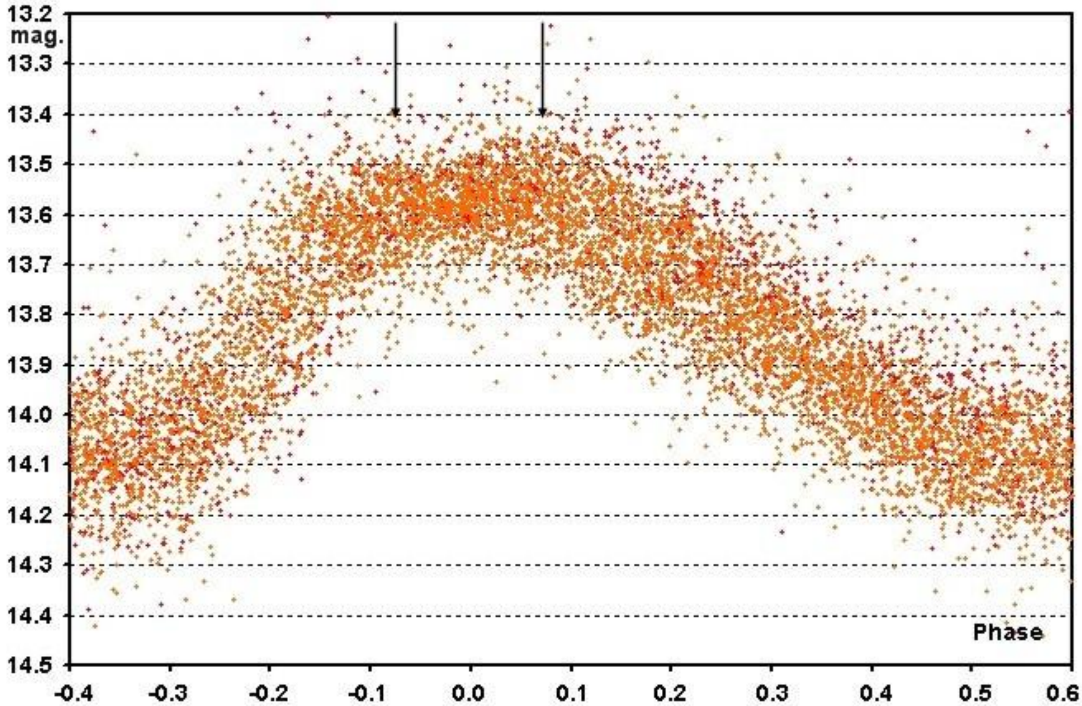

Fig. 1: The measurements of camera 1.44 reduced with ephemeris (1).
The peaks of the apparent double max. are marked with arrows.

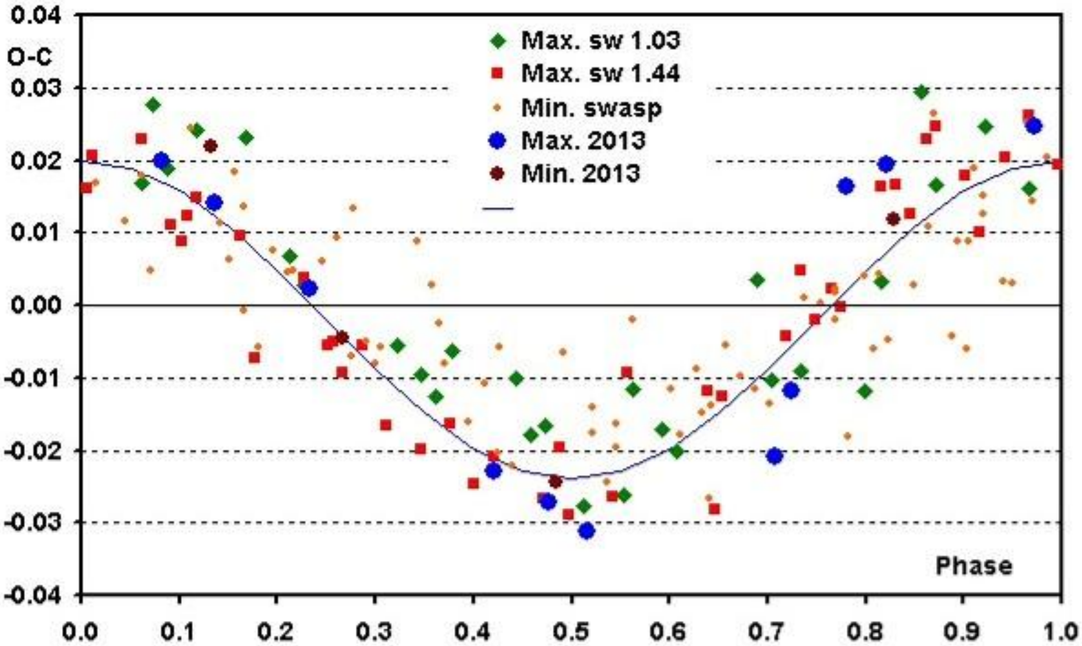

Fig. 2: The derived times of extrema, reduced with the Blazhko period P_B = 20.26 d.

Fig. 3 shows a particularly densely covered series from SWASP camera 1.44. From 2008-06-23 to 2008-07-13, the phase shifting of the max. over one Blazhko cycle can be closely followed. The shape of the second last LC (JD 4659) illustrates a peculiarity in the cycle, which will be described in more detail below.

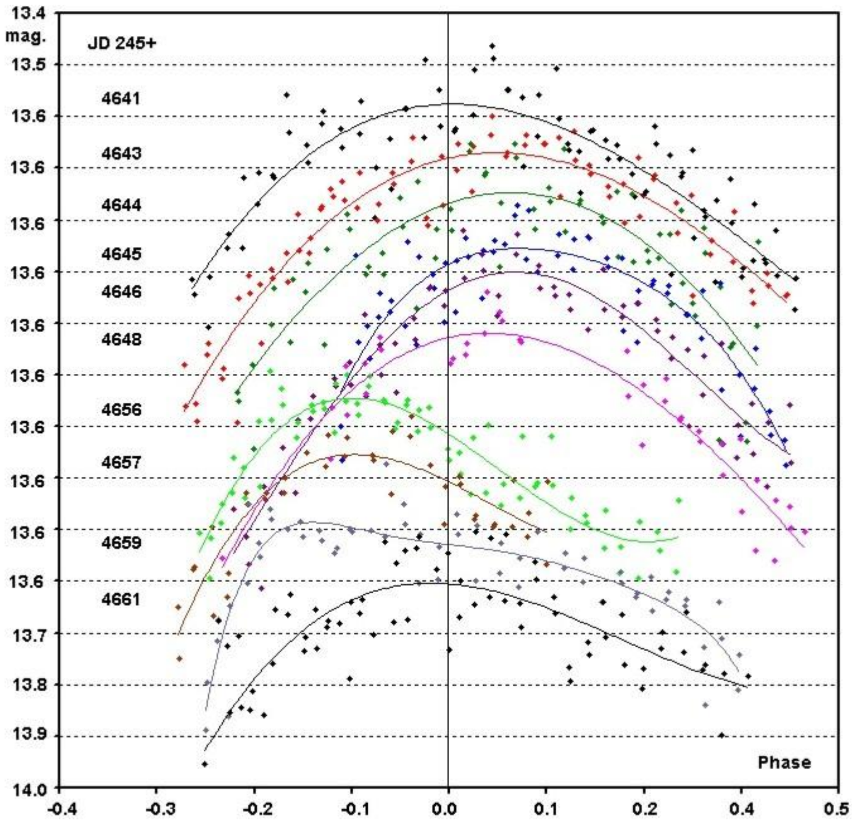

Fig. 3: A sample of SWASP LCs covering one Blazhko cycle. For clarity, the LCs are limited on both sides of the max. and shifted by 0.1 mag.

Another way to illustrate the behaviour of the star during the Blazhko cycle is shown in Fig. 4. The (O-C) values of the max. timings have been taken as abscissa and their corresponding magnitudes as ordinate, so that the Blazhko cycle is shown as a closed loop. In Le Borgne et al. [5], a great diversity of cycle shapes is shown. The shape of the cycle seems to be characteristic for a given Blazhko RR Lyrae star.

The slight differences in the heights of the max. shown in Fig. 1 suggest that the Blazhko effect affects not only the phase but – to some extent – also the amplitude of the pulsations. Because of this, one would expect an ellipse instead of a horizontal line in the diagram in Fig. 4. However, the amplitude modulations get lost in the observational scatter and, consequently, are not apparent in this diagram.

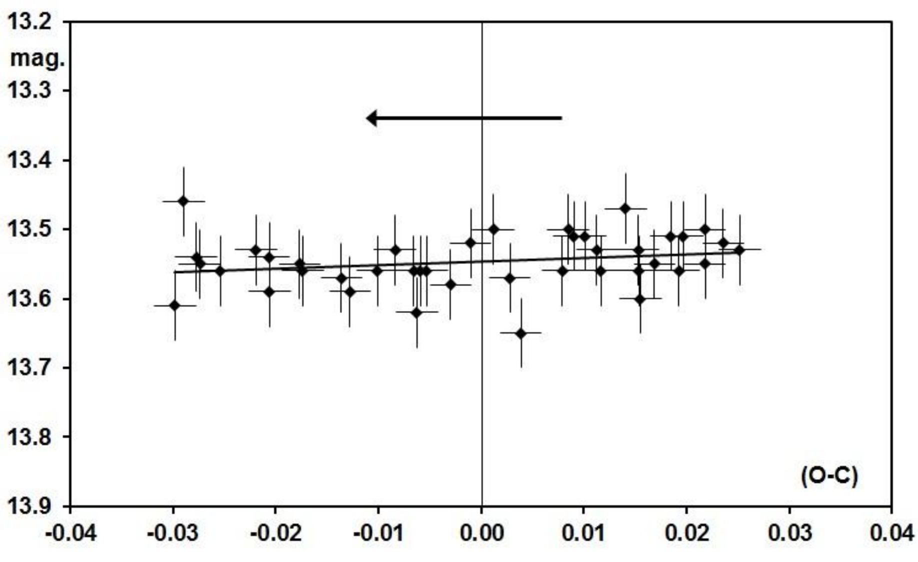

Fig. 4: The phase swing of the max. proceeds counterclockwise during the Blazhko cycle.

1.2. The 2013 measurements

In 13 nights from 2013-07-18 to 2013-08-20, extended image series could be won under mostly good sky conditions with a 10” SCT in a semi-automated mode and a SBIG ST8XME camera. With an exposition time of 120 s in the 2x2 binning mode, a total of 1,710 measurements could be won; the corresponding light curves are shown in Fig. 5. To increase the S/N ratio, no filter was used. Twilight sky-flat images were used for flatfield corrections. The reductions were performed with the Muniwin reduction program [6].

It is always recommended to choose reference stars with spectral classes matching the variable as closely as possible, but this information is usually not available for relatively faint stars. In their discovery publications, Bernhard et al. make use of the (J-K) index as an approximate indicator of the spectral class. The index employs the infrared J (1120 nm) and K (2190 nm) magnitudes derived from the 2MASS or CMC14 catalogues. A correlation between spectral classes and (J-K) index has been established in [7]. Similar tables can be found in [8] and [9]. A comparison shows that – in a spectral range from B8 to M0 –, the agreement is quite good. At least for main sequence stars, the (J-K) index seems to be a valuable spectral class indicator.

Star	CMC14	r mag.	J mag.	K mag	(J-K) Index	~Sp. Kl.
Var.	181448.1+471003	14.102	13.508	13.328	0.18	F0
C	181505.2+471309	14.075	12.927	12.491	0.44	G6
C1	181442.6+471329	13.998	12.920	12.467	0.45	G6
C2	181448.0+471238	13.788	12.571	12.049	0.52	K0
C3	181439.0+470900	14.190	12.963	12.446	0.52	K0

Table 1: The variable, the reference stars and their estimated spectral class.

Furthermore, J-K indices are often available via Guide 9.0 [10], so that an appropriate selection of reference stars could be made. In the present case, an exact match to the spectral class of the variable was not available in the field of the camera. Nevertheless, a comparison of the reference stars to one another showed no influence of differential extinction through variable airmass.

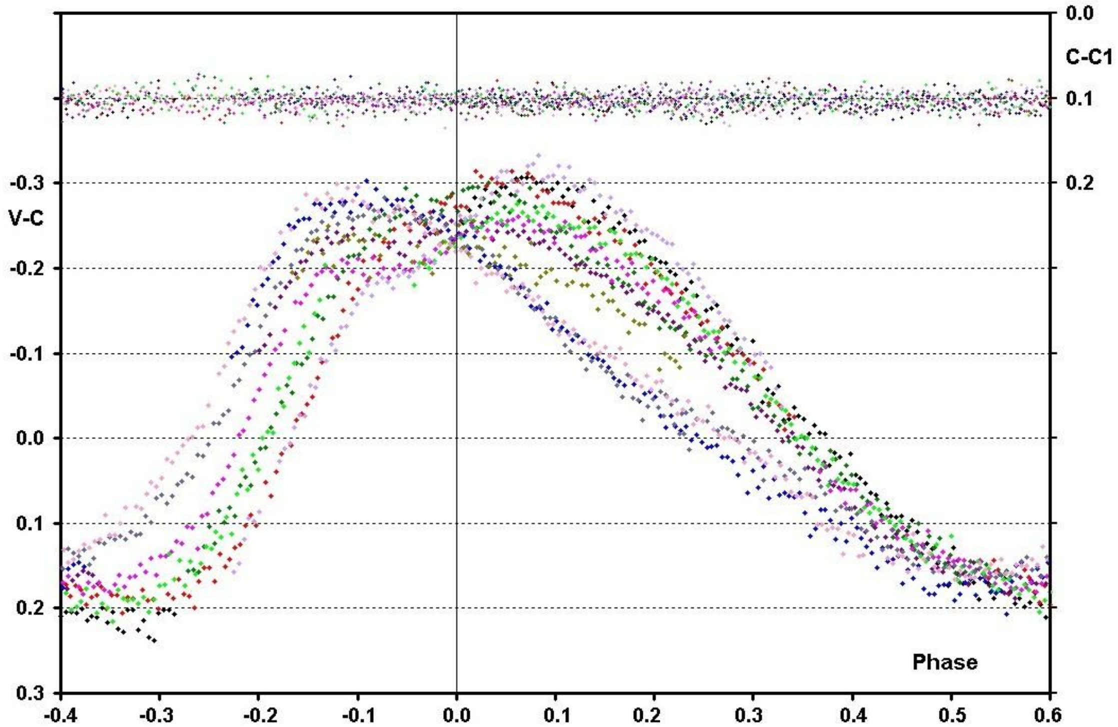

Fig. 5: An overview of the LCs won in the 2013 observation season, reduced with ephemeris (1).

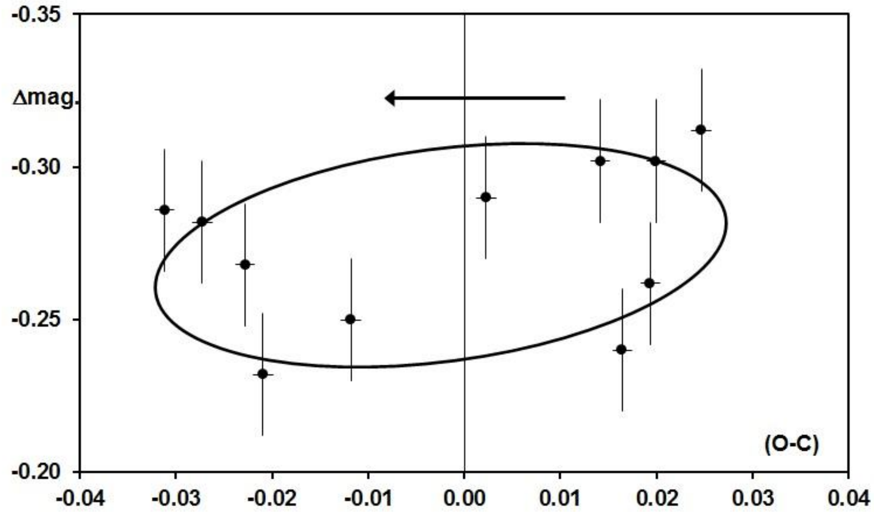

Fig. 6: The corresponding Blazhko cycle.

A little more than one Blazhko cycle was covered (cf. the LCs in Fig. 5). The observed behaviour is very similar to what has been observed in the SWASP data. Therefore, it seems that – at least from 2004 until now – the Blazhko period remained essentially constant. Additionally, the small magnitude differences in the heights of the max. suggested in Fig. 1 could be recorded in more detail, which leads to the cycle diagram shown in Fig. 6. A double max. is observed during parts of the cycle (at JD 6505 and JD 6506; cf. Fig 7). As the max. are coming in later, the left peak of this double max. seems to get progressively fainter while the right peak gains in brightness. Only continued observations could show if this phenomenon occurs each cycle.

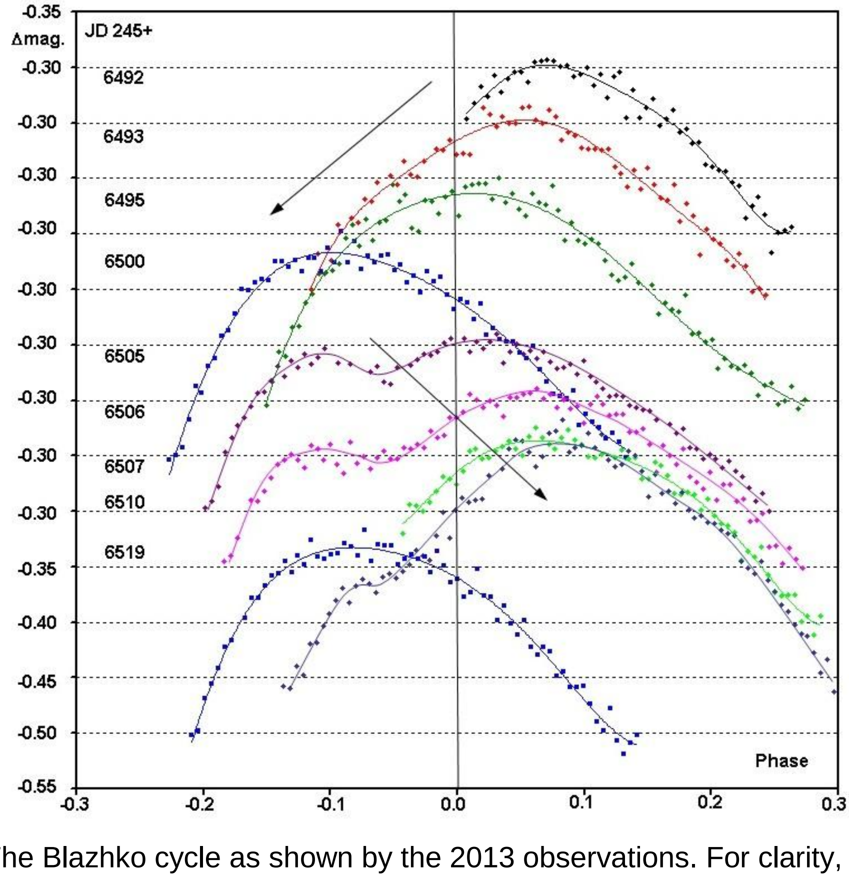

Fig. 7: The Blazhko cycle as shown by the 2013 observations. For clarity, the LCs are limited on both sides of the max. and shifted by 0.05 mag.

From the 2013 observations, the times of 11 max. and 4 min. could be determined and, in combination with the SWASP extrema, the ephemeris

$$\text{HJD (Max.)} = 2456495.4317(37) + 0.27719643(46) \text{ d} \times \text{E}. \qquad (1)$$

was derived. The deviations of the min. times were calculated with the ephemeris

$$\text{HJD (Min.)} = 2456516.3877(38) + 0.27719676(42) \text{ d} \times \text{E}. \qquad (2)$$

The times of all observed extrema yield the (O-C) diagram presented in Fig. 8 and are tabulated in the appendix.

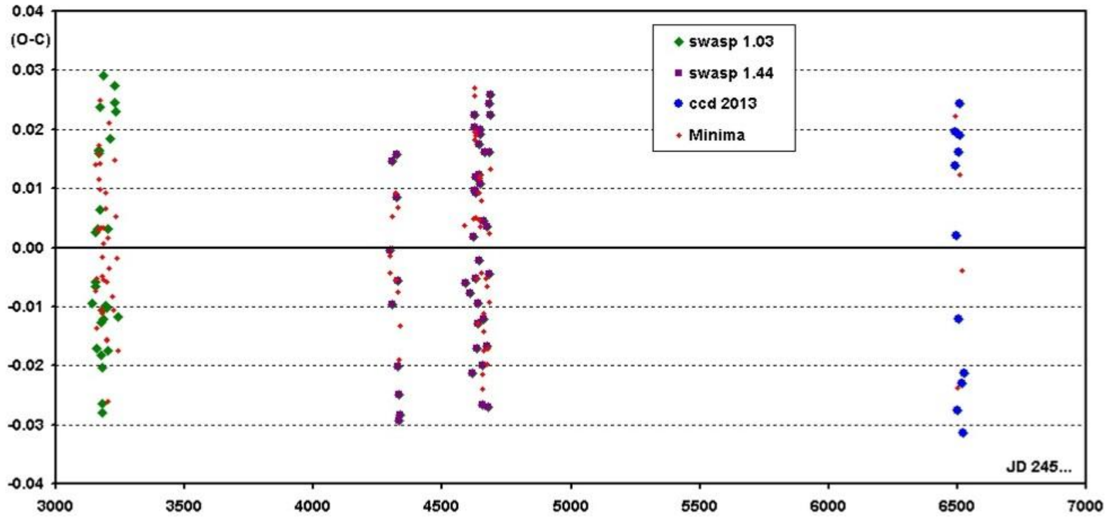

Fig. 8: (O-C) diagram with the SWASP and the 2013 extrema reduced with ephemeris (1).

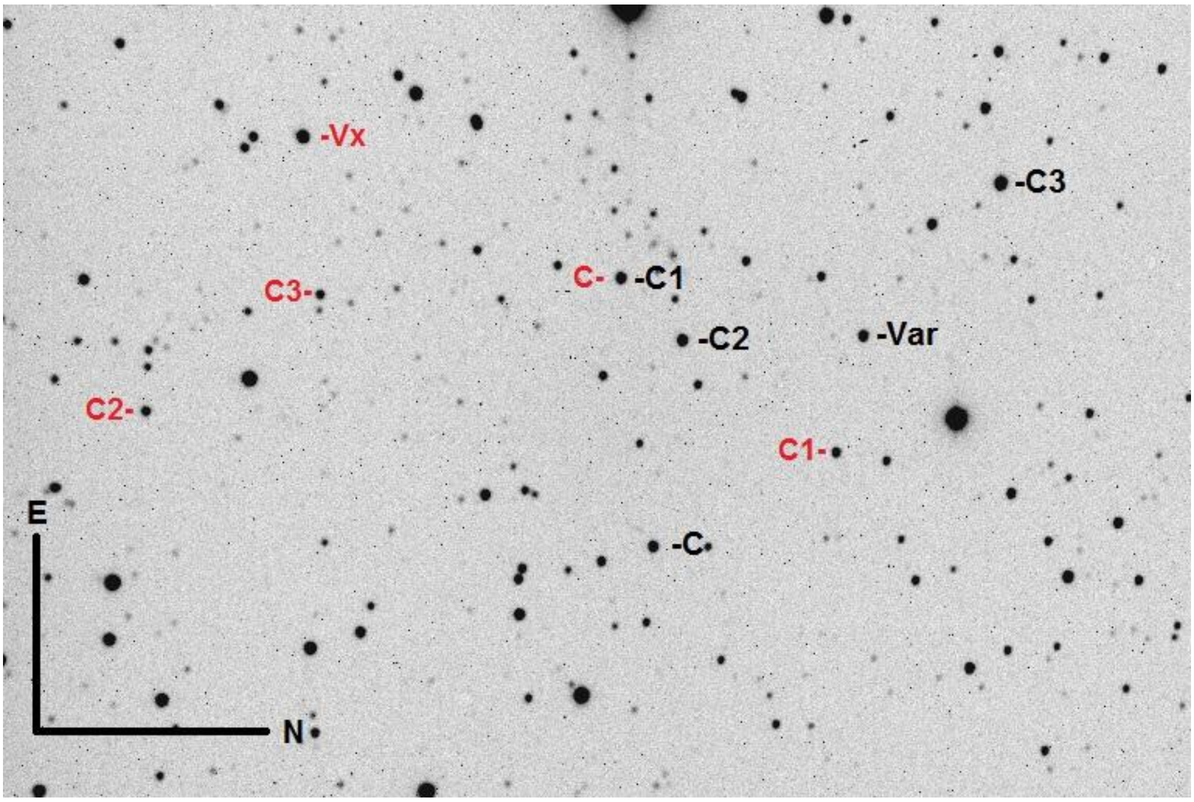

Fig. 9: The 20´ x 13´ field of the camera with the RR Lyrae star (Var), the new variable (Vx) and their reference stars.

2.Vx: GSC 2.3 N0ZY002187 (18 14 26.76 +47 19 09.38), 2MASS J18142676+479096

The CMC14 catalogue lists an R magnitude of 15.19 mag. for this star. The faintness of the object leads to increased scatter, so that the mean of five consecutive measurements was taken. In the LC (Fig. 10), the standard deviation of each point has been indicated. The star is probably a short period eclipsing variable (of W UMa type?) with shallow, 0.15 mag. deep eclipses. There does not seem to be a difference in depth between both minima, so that min. I was taken arbitrary. Six times of min. I and min. II (Table 2) were derived and lead to the ephemeris

HJD (Min.) = 2456493.3980(6) + 0.340055(12) d x E. (3)

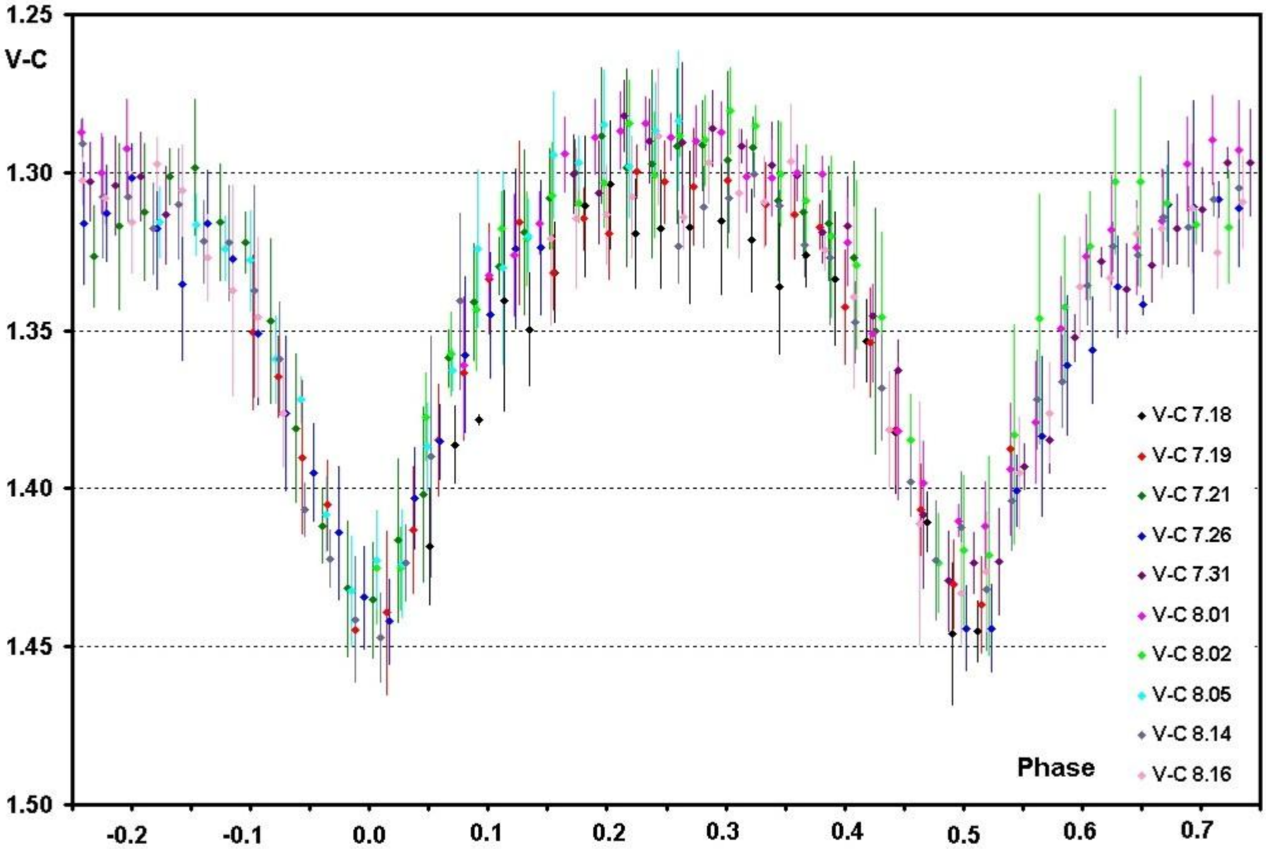

Fig. 10: The LC of GSC2.3 N0ZY002187 shows shallow eclipses with a period of 8 ¼ h.

J.D. Hel.		Epoch	(O-C)	J.D. Hel.		Epoch	(O-C)
2456493.400	Min I	0.0	0.002	2456507.509	Min II	41.5	-0.001
2456493.567	Min II	0.5	-0.001	2456510.401	Min I	50.0	0.000
2456495.437	Min I	6.0	-0.001	2456519.412	Min II	76.5	0.000
2456500.539	Min I	21.0	0.000	2456519.581	Min I	77.0	-0.001
2456505.472	Min II	35.5	0.002	2456521.454	Min II	82.5	0.001
2456506.490	Min II	38.5	0.000	2456525.363	Min I	94.0	0.000

Table 2: Minima of GSC2.3 N0ZY002187.

Acknowledgements:

This paper makes use of data from the DR1 of the WASP data (Butters et al. 2010) as provided by the WASP consortium, and the computing and storage facilities at the CERIT Scientific Cloud, reg. no. CZ.1.05/3.2.00/08.0144, which is operated by Masaryk University, Czech Republic. It also made use of the VizieR and Aladin databases operated at the Centre de Données Astronomiques (Strasbourg) in France. I would like to thank Stefan Hümmerich for improving the manuscript and Klaus Bernhard for advice.

Literature:

[1] Bernhard, K., Srdoc, G., Hümmerich, S., Drei neue RR Lyrae Sterne, BAV Rundbrief, 3/2013, p. 159, http://www.bav-astro.de/rb/rb2013-3/159.pdf

[2] SuperWASP Public archive, http://wasp.cerit-sc.cz/form

[3] The Catalina Sky Survey, http://www.lpl.arizona.edu/css/

[4] Groebel, R., GSC 02626-00896: an RR Lyrae star with a ceasing Blazhko effect and three new variables in the field, http://arxiv.org/abs/1307.6454

[5] Le Borgne, J. F. et al., 2007, The all–Sky GEOS RR Lyr Survey with the TAROT Telescope, Analysis of the Blazhko Effect, http://arxiv.org/abs/1205.6397

[6] Motl, D., http://c-munipack.sourceforge.net/

[7] Intrinsic colours as a function of spectral type, http://www.stsci.edu/~inr/intrins.html

[8] Bessell, M. S. and Brett, J. M., JHKLM photometry - Standard systems, passbands, and intrinsic colors, PASP, vol. 100, Sept. 1988, p. 1143,

http://articles.adsabs.harvard.edu/full/1988PASP..100.1134B

[9] Stead, J. J., and Hoare, M. G., 2002, New Empirical Intrinsic Colours for the 2MASS and UKIDSS Photometric Systems,

http://www.ast.leeds.ac.uk/~phy2j2s/Intrinsic_Stead10.pdf

[10] Guide 9.0, http://www.projectpluto.com/

Translation of the german version in BAV Rundbrief 32,228 (2013)

Rainer Gröbel, Blütenstr. 19, 90542 Eckental, Germany, rainer.groebel@web.de

Appendix: Maxima and minima of the RR Lyrae star GSC 03529-02286.

HJD Max.	W	(O-C)	HJD Max.	W	(O-C)		HJD Min.	W	(O-C)	HJD Min.	W	(O-C)
2453141.623	5	-0.009	2454621.586	5	0.002		2453152.619	5	0.014	2454328.466	5	-0.008
2453151.614	5	0.003	2454623.547	5	0.023		2453154.538	5	-0.007	2454333.444	5	-0.019
2453153.546	5	-0.006	2454624.643	5	0.010		2453155.649	5	-0.005	2454335.390	5	-0.014
2453154.654	5	-0.006	2454626.594	5	0.021		2453157.581	5	-0.014	2454584.607	5	0.004
2453156.584	5	-0.017	2454628.526	5	0.012		2453162.587	5	0.003	2454622.584	5	0.005
2453163.534	5	0.003	2454629.632	5	0.009		2453164.536	5	0.012	2454623.715	5	0.027
2453164.656	5	0.017	2454631.558	5	-0.005		2453165.649	5	0.016	2454624.539	5	0.019
2453166.596	5	0.016	2454632.655	5	-0.017		2453167.591	5	0.017	2454625.654	5	0.025
2453168.537	5	0.017	2454637.652	5	-0.009		2453169.539	5	0.025	2454627.587	5	0.018
2453169.653	5	0.024	2454639.589	5	-0.013		2453170.637	5	0.014	2454629.528	5	0.019
2453171.576	5	0.007	2454641.540	5	-0.002		2453172.573	5	0.010	2454630.623	5	0.005
2453174.606	5	-0.012	2454643.495	5	0.013		2453174.507	5	0.003	2454632.553	5	-0.006
2453176.541	5	-0.018	2454644.609	5	0.018		2453175.602	5	-0.010	2454640.584	5	-0.013
2453177.640	5	-0.028	2454645.443	5	0.020		2453178.660	5	-0.002	2454642.542	5	0.004
2453178.473	5	-0.026	2454646.551	5	0.019		2453179.482	5	-0.011	2454644.487	5	0.009
2453179.588	5	-0.020	2454648.483	5	0.011		2453180.597	5	-0.005	2454645.590	5	0.003
2453181.538	5	-0.010	2454656.491	5	-0.020		2453182.543	5	0.001	2454647.539	5	0.012
2453183.477	5	-0.012	2454657.593	5	-0.026		2453184.486	5	0.003	2454649.479	5	0.011
2453184.627	5	0.029	2454659.548	5	-0.012		2453185.586	5	-0.005	2454650.584	5	0.008
2453194.567	5	-0.010	2454661.505	5	0.005		2453192.528	5	0.007	2454652.512	5	-0.005
2453196.507	5	-0.010	2454663.457	5	0.016		2453194.471	5	0.009	2454655.544	5	-0.022
2453199.549	5	-0.017	2454671.483	5	0.004		2453195.555	5	-0.016	2454657.482	5	-0.024
2453201.510	5	0.003	2454674.512	5	-0.016		2453197.505	5	-0.006	2454659.432	5	-0.015
2453209.564	5	0.019	2454676.442	5	-0.027		2453198.604	5	-0.016	2454660.544	5	-0.011
2453226.479	5	0.025	2454681.454	5	-0.004		2453200.534	5	-0.026	2454662.478	5	-0.018
2453229.531	5	0.028	2454683.415	5	0.016		2453202.502	5	0.002	2454670.529	5	-0.005
2453231.467	5	0.023	2454684.532	5	0.025		2453205.546	5	-0.004	2454672.468	5	-0.007
2453239.471	5	-0.011	2454686.474	5	0.026		2453207.511	5	0.021	2454675.504	5	-0.020
2454297.541	5	0.000	2454688.411	5	0.023		2453220.510	5	-0.008	2454677.447	5	-0.017
2454304.486	5	0.015	2456492.403	10	0.020		2453222.448	5	-0.011	2454680.504	5	-0.010
2454307.511	5	-0.009	2456493.506	10	0.014		2453227.463	5	0.015	2454682.456	5	0.002
2454322.505	5	0.016	2456495.434	10	0.002		2453232.443	5	0.005	2454685.516	5	0.013
2454324.438	5	0.009	2456500.394	10	-0.027		2453235.485	5	-0.002	2456493.402	10	0.022
2454327.473	5	-0.005	2456505.399	10	-0.012		2453240.459	5	-0.017	2456500.563	10	-0.024
2454329.399	5	-0.020	2456506.536	10	0.016		2454297.426	5	-0.002	2456507.529	10	0.012
2454330.503	5	-0.025	2456507.371	10	0.019		2454298.532	5	-0.004	2456516.383	10	-0.005
2454332.439	5	-0.029	2456510.425	10	0.025		2454303.531	5	0.005			
2454335.489	5	-0.028	2456519.525	10	-0.023		2454305.466	5	0.000			
2454591.641	5	-0.006	2456521.457	10	-0.031		2454318.489	5	-0.006			
2454609.657	5	-0.007	2456525.348	5	-0.021		2454320.444	5	0.009			
2454614.633	5	-0.021					2454325.431	5	0.006			