GEOS RR Lyrae Survey: Blazhko Period Measurement of Three RRab Stars—CX Lyrae, NU Aurigae, and VY Coronae Borealis

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Abstract We present the results of collaborative observations of three RR Lyrae stars (CX Lyr, NU Aur, and VY CrB) which have a strong Blazhko effect. This work has been initiated and performed in the framework of the GEOS RR Lyr Survey (Groupe Européen d'Observations Stellaires). From the measured light curves, we have determined the times and the magnitudes at maximum. The times of maxima have been compared to ephemerides to obtain the (O–C) values and from a period analysis of these (O–C) values, the Blazhko period is derived. The Blazhko periods of NU Aur (114.8 days) and VY CrB (32.3 days) are reported here for the first time and a more accurate period for CX Lyr (68.3 days) has been obtained. The three stars are subject to strong Blazhko effect, but this effect has different characteristics for each of them. When we compare the variations of magnitude at maximum and variations of (O–C) values with

respect to the Blazhko phase, these variations are in phase, in opposition, or even in quadrature.

1. Introduction

The main objective of the GEOS RR Lyr Survey is to follow the variations of period and Blazhko effect of bright and well-studied RR Lyrae stars. These variations are followed in the long term with TAROT robotic telescopes (Le Borgne *et al.* 2007 and Poretti *et al.* 2008). The second objective of the survey is the observation of Blazhko effect of under-studied RR Lyrae stars. The results presented here are in keeping with this objective.

The RR Lyrae stars of Bailey type ab (RRab) are pulsating stars with a period between 0.4 and 0.7 day. Some RRab stars exhibit a phase and amplitude modulation. This phenomenon, known for a century, is called the Blazhko effect. It is recognized that this effect is still not well understood. RRab stars exhibiting the Blazhko effect appear to show a variety of characteristics. Recent continuous, high precision photometry from the Kepler satellite documents a period doubling for some RR Lyrae stars (Szabó *et al.* 2010). With our ground–based small aperture telescopes and their limited photometric accuracy, we attempt to determine the Blazhko period of neglected RRab stars. Monitoring during several years is needed to determine the Blazhko period and to characterize the Blazhko behavior. We have analyzed the variations of the magnitude at maximum and (O–C) value with respect to the Blazhko phase for three different stars (CX Lyr, NU Aur, and VY CrB).

After dark and flat field corrections with the MAXIM DL software (Diffraction Limited 2004), aperture photometry was performed using either AIP4WIN (Berry and Burnell 2001) or LESVEPHOTOMETRY (de Ponthière 2010), a custom software which also evaluates the SNR and estimates magnitude errors. No color corrections have been applied to the measured magnitudes. The times of maxima of the light curves have been evaluated with the same custom software fitting the light curve with a smoothing spline function (Reinsch 1967). We have used the ANOVA algorithm of PERANSO (Vanmunster 2007) to derive the Blazhko period from the times of maxima.

2. CX Lyr

The star CX Lyr is classified in the *General Catalogue of Variable Stars* (GCVS; Samus *et al.* 2011) as an RRab variable star with a period of 0.61664495 day. CX Lyr observations during the second half of 2008 (JD 2454637 to 2454783) have been previously reported by de Ponthière *et al.* (2009). During a new observation campaign from 2009 to 2011 (JD 2455041 to 2455807), we obtained forty–one new maxima.

The comparison stars used by the authors are given in Table 1. The star coordinates and magnitudes in *B* and *V* bands were obtained from the NOMAD catalogue (Zacharias *et al.* 2011). C1 was used as magnitude reference and the others as check stars. The choice of different comparison stars creates a magnitude offset due to their color differences. This offset has been evaluated by comparing the magnitudes of a common check star and taken into account. Table 2 provides the list of these new observations and Figure 1 shows the (O–C) values. For the sake of completeness, observations obtained by G. Maintz (Huebscher *et al.* 2008, 2010) and older GEOS observations are included in the table as they are used in the present analysis.

A linear regression of all available (O–C) values has provided a new pulsation period of 0.616758 day. The (O–C) values have been re–evaluated with this new pulsation period. The new elements are:

$$\mathrm{HJD} = 2454677.5692 \pm 0.0031 + (0.6167582 \pm 0.0000031)\ \mathrm{E} \qquad (1)$$

These values are very close to the values reported previously (de Ponthiere *et al.* 2009).

$$\mathrm{HJD} = 2454677.5688 \pm 0.0037 + (0.61675 \pm 0.000024\ )\ \mathrm{E} \qquad (2)$$

The Blazhko period was determined by a period analysis of the (O–C) values with the ANOVA algorithm. The most significant period is 68.3 ± 0.4 days (5.34 c/y). The periodogram presented in Figure 2 indicates other peaks at 56.6 days (6.45 c/y), 84.1 days (4.34 c/y), and 113.3 days (3.22 c/y) which are one-year sampling aliases.

There is also another peak at 136 days, that is, twice the most significant period. Data from the year 2010 (JD 2455300 to 2455500) indicate that the successive Blazhko cycles are not identical (Figure 1). The variations of successive cycles create spectral response at a multiple of the fundamental period. An (O–C) folded light curve at 136 days, would show two maxima. A similar period analysis of the magnitude at maximum with the ANOVA algorithm has provided similar conclusions.

The folded (O–C) and magnitude at maximum curves versus the Blazhko phase are given in Figure 3a and 3b. It can be seen that these two curves are nearly in phase, with the minima reached at the same Blazhko phase.

3. NU Aur

The star NU Aur is classified in the GCVS (Samus *et al.* 2011) as an RRab variable star with a period of 0.53941672 day and a Blazhko period of 179 days. During a first observation campaign, between December 2006 and February 2007 (JD 2454081 to 2454135), the eighteen obtained maxima clearly showed a strong Blazhko effect but did not allow a determination of the Blazhko period. The observation of seventy–five maxima resulted from a second series of observations between December 2008 and March 2011

(JD 2454752 to 2454640). The comparison stars are documented in Table 3. Star coordinates and *B* and *V* magnitudes are those found in the AAVSO's Comparison Star Database (VSD). The times of maximum and (O–C) values are given in Table 4 and Figure 4. The observations of G.Maintz have already been published by Huebscher *et al.* (2009) and those of K. Menzies published by Samolyk (2011).

A linear regression on the (O–C) values has provided the following elements:

$$HJD = 2454752.4603 \pm 0.0014 + (0.5394148 \pm 0.0000015)\,E \qquad (3)$$

To determine the Blazhko period we have performed a period analysis of the (O–C) values with the ANOVA algorithm. The corresponding periodogram presented in Fig. 5a indicates that the values of the four prominent peaks include:

Period (days)	Cycles / year	Peak value
114.4	3.192	49.6
170.1	2.148	56.7
227.1	1.600	47.3
339.6	1.074	53.4

The first two peaks (114.4 ± 1.7 and 170.1 ± 2.6 days) are an alias pair. One frequency is the alias at one cycle per year of the other. The third period (227.1) days is approximately double the first one (114.4). The period of 170.1 days is close to the value reported in the GCVS (175 days). These aliases are artifacts arising from gaps between normal 6–month observing seasons. With the Spectral Window tool in PERANSO, we have tried to determine which peaks are artifacts of the seasonal sampling. This algorithm calculates the pattern caused by the structure of gaps in the observations. The output of the Spectral Window is given in Figure 5b, where it can be seen that the artifact peaks are broad. The list of prominent peaks is:

Period (days)	Cycles / year	Peak value
91.1	4.007	0.08
103.4	3.536	0.06
128.8	2.834	0.07
145.2	2.517	0.16
181.4	2.013	0.12
244.2	1.494	0.28
362.2	1.008	0.60

This Spectral Window analysis indicates that the first peak (114.4 days) of the ANOVA analysis is not an artifact due to seasonal sampling. The second peak (170.1 days) is close to the 181.4 peak of the Spectral Window analysis and could be an artifact. The Blazhko period is probably 114.4 ± 1.7 days, but we can not eliminate the second possible period of 170.1 ± 2.6 days. More observations are needed to remove this ambiguity.

Using the adopted period of 114.4 days, the folded (O–C) and magnitude at maximum curves versus the Blazhko phase are given in Figure 6a and 6b. It can be seen that these two curves are not in phase as was the case for CX Lyr. For NU Aur star the two curves are in quadrature.

4. VY CrB

The star VY CrB is classified in the GCVS (Samus *et al.* 2011) as an RRab variable star. VY CrB is also designated as GSC 2576–0980 (Space Telescope Science Institute 2001). It was identified as an RRab star on photographic plates by Antipin (1996). VY CrB is herein identified as Antipin's Var 23 with a period of 0.462957 day.

We observed two maxima of VY CrB in April 2007 (JD 2454215 and 2454216) and forty–nine maxima between April 2010 and August 2011 (JD 2455302 to 2455784). The selected comparison stars are given in Table 5. Star coordinates and *B* and *V* magnitude are obtained from the NOMAD catalogue. The times of maximum and (O–C) values are given in Table 6 and Figure 7. This table also includes a previous observation obtained by A. Paschke (Agerer and Huebscher 2002).

A linear regression of the (O–C) values has provided the following elements:

$$\mathrm{HJD} = 2455302.5032 \pm 0.0013 + (0.4629461 \pm 0.0000010)\,\mathrm{E} \qquad (4)$$

As for the other stars, the Blazhko period has been derived with the ANOVA algorithm applied to the (O–C) values. The corresponding periodogram is given in Figure 8. The periods for the two prominent peaks are: 32.3 ± 0.1 and 64.6 ± 0.2 days, which differ by a factor of two. As for CX Lyr, the non–repetitive behavior of the Blazhko effect generates spectral response at multiples of the fundamental period. With a Blazhko period of 64.4 days we would have two (O–C) maxima per cycle, so we retained the Blazhko period value of 32.3 ± 0.1 days.

The folded (O–C) and magnitude at maximum versus the Blazhko period of 32.3 days are given in Figure 9a and 9b. It can be seen that these two curves are in phase opposition: the maximum value of (O–C) occurs when the magnitude at maximum is at its minimum value.

5. Blazhko behavior comparison

It is interesting to plot the magnitude at maximum versus the (O–C) values. If these quantities were varying in time as sinusoids and were in phase, the resulting graph would be a straight line in the first and third quadrants. If they were in phase opposition, the graph would be a straight line in the second and fourth quadrants and if they were in quadrature the graph would exhibit a circle. The periodical variations of magnitude at maximum and the (O–C) values are not sinusoidal, but the corresponding parametric representation will nevertheless provide useful information.

These graphs for the three stars are given in Figure 10. For the CX Lyr, the points are scattered along two segments forming a right angle but the general trend is a slope at 45 degrees indicating that (O–C) and magnitude at maximum are in phase as shown in Figures 3a and 3b. The points along the vertical segment correspond to the Blazhko phases between 0.0 and 0.5 and the other points along the horizontal segment correspond to the second part of the Blazhko period.

In the diagram of NU Aur, the points with a magnitude fainter than 12.9 are grouped on a circle, the magnitude at maximum and (O–C) values are in phase quadrature as shown in Figures 6a and 6b. The group of points with a magnitude fainter than 12.9 are created by the non–repetitive behavior from Blazhko cycles. The full data set for NU Aur covers more than ten Blazhko cycles.

In the VY CrB graph, the points are scattered along a curve with a slope of about 135 degrees. The magnitude at maximum and (O–C) curves are in phase opposition.

For CX Lyr and VY CrB, the (O–C) errors are larger when the magnitudes at maximum are at their greatest value. This is partially due to a lower SNR but mainly because the light curve at maximum is flatter, which leads to a less precise maximum measurement.

6. Conclusions

This study indicates that regular observations over several seasons or years by amateurs can lead to the characterization of the Blazhko effect of RR Lyr stars: this is one of the main objectives of the professional–amateur program "GEOS RR Lyr Survey." These results should encourage amateurs to join in measurement campaigns.

The measurement of RR Lyrae stars having a strong Blazhko effect highlights the fact that this effect is not standard from one star to another, as satellite-based observations (CoRot and Kepler) have shown. Each star has a particular behavior and it may not repeat exactly from one cycle to another. A complete astrophysical model of Blazhko effect for RRab stars should be able to explain these behavior differences.

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Table 1. Comparison stars for CX Lyr.

Identification *R.A. (2000)* *h m s*	*Dec. (2000)* *° ′ ″*	*B*	*V*	*B–V*	*DPP*	*Hambsch*	*Sabo*
GSC 2121–2818							
18 51 51.48	+28 49 08.15	11.129	10.548	0.581	C1		
GSC 2121–2053							
18 51 37.00	+28 51 16.32	11.054	10.565	0.489	C2		C2
GSC 2121–1980							
18 51 14.25	+28 43 37.01	13.29	12.74	0.55	C3	C1	C1
GSC 2121–2842							
18 51 07.01	+28 45 12.52	13.8	13.1	0.7		C2	

Table 2. List of measured maxima of CX Lyr.

Maximum HJD	*Error*	*O–C (day)*	*E*	*Magnitude*	*Error*	*Filter*	*Observer*
2454238.4240	0.0050	–0.0139	–712	—	—	—	F. Fumagalli
2454278.5276	0.0014	0.0004	–647	—	—	—	F. Fumagalli
2454280.3802	0.0015	0.0027	–644	—	—	—	F. Fumagalli
2454362.4056	0.0014	–0.0007	–511	—	—	—	G. Maintz
2454637.4929	0.0026	0.0125	–65	12.329	0.050	V	F.-J. Hambsch
2454661.5051	0.0020	–0.0289	–26	12.308	0.050	V	F.-J. Hambsch
2454677.5688	0.0018	–0.0009	0	12.152	0.006	V	P. de Ponthière
2454685.5930	0.0020	0.0055	13	12.062	0.026	V	P. de Ponthière
2454692.3815	0.0013	0.0096	24	12.051	0.005	V	P. de Ponthière
2454708.4197	0.0019	0.0121	50	12.235	0.006	V	P. de Ponthière
2454711.5050	0.0040	0.0136	55	12.237	0.040	V	P. de Ponthière
2454719.5020	0.0050	–0.0072	68	12.297	0.026	V	P. de Ponthière
2454724.4300	0.0040	–0.0133	76	12.331	0.007	V	P. de Ponthière
2454729.3630	0.0030	–0.0144	84	12.324	0.006	V	P. de Ponthière
2454750.3518	0.0016	0.0047	118	12.134	0.012	V	P. de Ponthière
2454758.3736	0.0012	0.0086	131	12.156	0.020	V	P. de Ponthière
2454774.4100	0.0030	0.0093	157	12.293	0.020	V	P. de Ponthière
2454782.3940	0.0030	–0.0246	170	12.363	0.022	V	P. de Ponthière
2454983.4954	0.0024	0.0137	496	12.333	0.008	V	P. de Ponthière
2455041.4761	0.0032	0.0191	590	12.158	0.008	V	P. de Ponthière

Table continued on next page

Table 2. List of measured maxima of CX Lyr, cont.

Maximum HJD	*Error*	*O–C (day)*	*E*	*Magnitude*	*Error*	*Filter*	*Observer*
2455046.4025	0.0025	0.0115	598	12.296	0.013	V	F.-J. Hambsch
2455049.4886	0.0035	0.0138	603	12.294	0.010	V	P. de Ponthière
2455052.5695	0.0085	0.0109	608	12.295	0.015	V	P. de Ponthière
2455057.4596	0.0060	–0.0331	616	—	—	V	G. Maintz
2455060.5485	0.0084	–0.0279	621	12.371	0.010	V	P. de Ponthière
2455062.3950	0.0010	–0.0317	624	—	—	V	G. Maintz
2455062.3977	0.0032	–0.0290	624	12.432	0.009	V	F.-J. Hambsch
2455094.5062	0.0025	0.0081	676	12.065	0.015	V	P. de Ponthière
2455096.3587	0.0015	0.0103	679	12.042	0.008	V	P. de Ponthière
2455295.5698	0.0015	0.0085	1002	12.087	0.011	V	P. de Ponthière
2455303.5902	0.0012	0.0111	1015	12.021	0.010	V	P. de Ponthière
2455308.5270	0.0020	0.0138	1023	12.024	0.011	V	P. de Ponthière
2455311.6080	0.0025	0.0110	1028	12.073	0.020	V	P. de Ponthière
2455312.8464	0.0018	0.0159	1030	12.162	0.012	V	F.-J. Hambsch
2455320.8601	0.0019	0.0117	1043	12.307	0.011	V	F.-J. Hambsch
2455333.7745	0.0040	–0.0258	1064	12.397	0.012	V	F.-J. Hambsch
2455353.5350	0.0025	–0.0015	1096	12.303	0.012	V	P. de Ponthière
2455363.4131	0.0025	0.0084	1112	12.122	0.030	V	P. de Ponthière
2455369.5828	0.0020	0.0106	1122	12.050	0.010	V	P. de Ponthière
2455374.5167	0.0020	0.0104	1130	12.030	0.010	V	P. de Ponthière
2455379.4518	0.0020	0.0114	1138	12.056	0.009	V	P. de Ponthière
2455382.5342	0.0015	0.0100	1143	12.121	0.009	V	P. de Ponthière
2455387.4662	0.0023	0.0080	1151	12.188	0.010	V	P. de Ponthière
2455392.3970	0.0030	0.0047	1159	12.286	0.010	V	P. de Ponthière
2455395.4753	0.0040	–0.0008	1164	12.337	0.009	V	P. de Ponthière
2455398.5497	0.0074	–0.0102	1169	12.364	0.009	V	P. de Ponthière
2455408.3959	0.0035	–0.0321	1185	12.325	0.010	V	P. de Ponthière
2455429.4044	0.0025	0.0066	1219	12.189	0.011	V	P. de Ponthière
2455440.5115	0.0017	0.0121	1237	11.988	0.009	V	P. de Ponthière
2455442.3601	0.0020	0.0104	1240	11.980	0.012	V	P. de Ponthière
2455445.4485	0.0015	0.0150	1245	12.009	0.008	V	P. de Ponthière
2455461.4862	0.0040	0.0170	1271	12.284	0.011	V	P. de Ponthière
2455470.7015	0.0065	–0.0191	1286	12.427	0.011	V	F.-J. Hambsch
2455479.3298	0.0047	–0.0254	1300	12.371	0.010	V	P. de Ponthière
2455492.3090	0.0075	0.0019	1321	12.347	0.018	V	P. de Ponthière
2455649.5879	0.0020	0.0075	1576	12.053	0.009	V	P. de Ponthière
2455670.5422	0.0044	–0.0080	1610	12.343	0.010	V	P. de Ponthière
2455713.7302	0.0013	0.0069	1680	12.025	0.006	V	K .Menzies
2455745.7679	0.0020	–0.0268	1732	12.464	0.004	V	R. Sabo
2455746.3925	0.0026	–0.0189	1733	12.401	0.013	V	P. de Ponthière
2455807.4625	0.0034	–0.0080	1832	12.366	0.010	V	P. de Ponthière

Table 3. Comparison stars for NU Aur.

Identification R.A. (2000) h m s	Dec. (2000) ° ′ ″	B	V	B–V	DPP	Hambsch	Menzies	Sabo
GSC 1857–1453								
05 08 58.82	+28 42 08	13.32	12.53	0.795	C1	C1	C1	C1
GSC 1857–1288								
05 08 59.15	+28 43 20.2		13.67			C2		
GSC 1857–1288								
05 08 59.17	+28 43 20.3	14.46	13.77	0.69	C2		C2	C2
GSC 1857–938								
05 08 34.00	+28 45 07.6	13.322	12.326	0.996	C3	C3	C3	C3

Table 4. List of measured maxima of NU Aur.

Maximum HJD	Error	O–C (day)	E	Magnitude	Error	Filter	Observer
2454081.4445	0.0100	0.0204	–1244	—	—	—	J.-M. Llapasset
2454083.5942	0.0005	0.0125	–1240	—	—	—	J.-M. Llapasset
2454088.4454	0.0010	0.0089	–1231	—	—	—	J.-M. Llapasset
2454089.5225	0.0005	0.0072	–1229	—	—	—	J.-M. Llapasset
2454090.6033	0.0005	0.0092	–1227	—	—	—	J.-M. Llapasset
2454091.6733	0.0010	0.0003	–1225	—	—	—	J.-M. Llapasset
2454096.5397	0.0005	0.0120	–1216	—	—	—	J.-M. Llapasset
2454100.3214	0.0005	0.0178	–1209	—	—	—	J.-M. Llapasset
2454107.3333	0.0010	0.0173	–1196	—	—	—	J.-M. Llapasset
2454114.3359	0.0005	0.0075	–1183	—	—	—	J.-M. Llapasset
2454121.3493	0.0005	0.0085	–1170	—	—	—	J.-M. Llapasset
2454128.3628	0.0010	0.0096	–1157	—	—	—	J.-M. Llapasset
2454135.3748	0.0005	0.0092	–1144	—	—	—	J.-M. Llapasset
2454456.3178	0.0004	–0.0001	–549	—	—	—	G. Maintz
2454752.4570	0.0040	0.0000	0	13.042	0.011	C	P. de Ponthière
2454759.4820	0.0030	0.0126	13	13.028	0.008	C	P. de Ponthière
2454774.5770	0.0020	0.0040	41	12.899	0.012	C	P. de Ponthière
2454787.5310	0.0040	0.0120	65	12.860	0.007	C	P. de Ponthière
2454801.0080	0.0030	0.0036	90	12.737	0.005	V	P. de Ponthière
2454804.7820	0.0040	0.0017	97	12.875	0.005	V	P. de Ponthière
2454808.0200	0.0030	0.0032	103	12.845	0.005	V	P. de Ponthière
2454827.4315	0.0018	–0.0043	139	12.854	0.007	C	P. de Ponthière
2454828.5107	0.0017	–0.0039	141	12.838	0.007	C	P. de Ponthière
2454829.5870	0.0030	–0.0064	143	12.846	0.009	C	P. de Ponthière
2454829.5900	0.0020	–0.0034	143	12.852	0.009	V	P. de Ponthière
2454830.6570	0.0030	–0.0153	145	12.878	0.009	V	P. de Ponthière

Table continued on following pages

Table 4. List of measured maxima of NU Aur, cont.

Maximum HJD	*Error*	*O–C (day)*	*E*	*Magnitude*	*Error*	*Filter*	*Observer*
2454830.6610	0.0030	–0.0113	145	12.902	0.014	V	P. de Ponthière
2454831.7451	0.0017	–0.0060	147	12.849	0.008	V	P. de Ponthière
2454832.8202	0.0016	–0.0097	149	12.875	0.008	V	P. de Ponthière
2454833.9020	0.0030	–0.0067	151	12.891	0.009	V	P. de Ponthière
2454838.7576	0.0014	–0.0059	160	12.931	0.011	V	P. de Ponthière
2454841.4540	0.0050	–0.0066	165	12.927	0.023	V	P. de Ponthière
2454843.6114	0.0018	–0.0068	169	12.936	0.013	V	P. de Ponthière
2454844.6863	0.0012	–0.0108	171	12.902	0.012	V	P. de Ponthière
2454845.7661	0.0015	–0.0098	173	12.900	0.011	V	P. de Ponthière
2454846.3070	0.0020	–0.0083	174	—	—	—	J.-M. Llapasset
2454846.8450	0.0020	–0.0097	175	12.898	0.010	V	P. de Ponthière
2454850.6150	0.0020	–0.0156	182	12.904	0.010	V	P. de Ponthière
2454851.6940	0.0040	–0.0155	184	12.946	0.009	V	P. de Ponthière
2454852.7740	0.0020	–0.0143	186	12.932	0.006	V	P. de Ponthière
2454857.6330	0.0040	–0.0100	195	13.018	0.008	V	P. de Ponthière
2454860.3380	0.0050	–0.0021	200	13.021	0.016	V	P. de Ponthière
2454861.4150	0.0040	–0.0039	202	13.040	0.018	V	P. de Ponthière
2454862.4960	0.0040	–0.0018	204	13.034	0.017	V	P. de Ponthière
2454884.6190	0.0018	0.0051	245	13.007	0.008	V	P. de Ponthière
2454887.3170	0.0020	0.0061	250	—	—	—	J.-M. Llapasset
2454888.3980	0.0020	0.0083	252	—	—	—	J.-M. Llapasset
2454891.6396	0.0030	0.0133	258	13.017	0.011	V	P. de Ponthière
2455100.9247	0.0031	0.0053	646	—	—	V	R. Sabo
2455106.8653	0.0036	0.0123	657	12.995	0.019	V	F.-J. Hambsch
2455113.8751	0.0028	0.0097	670	12.937	0.017	V	F.-J. Hambsch
2455114.9502	0.0040	0.0060	672	12.961	0.036	V	F.-J. Hambsch
2455119.8273	0.0035	0.0283	681	12.971	0.019	V	F.-J. Hambsch
2455120.8963	0.0029	0.0185	683	12.923	0.011	V	F.-J. Hambsch
2455121.9780	0.0023	0.0214	685	12.889	0.009	V	F.-J. Hambsch
2455122.5074	0.0030	0.0113	686	12.878	0.010	V	F.-J. Hambsch
2455127.9098	0.0034	0.0196	696	12.797	0.019	V	F.-J. Hambsch
2455128.9865	0.0039	0.0175	698	12.783	0.003	V	F.-J. Hambsch
2455135.9890	0.0120	0.0076	711	12.674	0.008	V	F.-J. Hambsch
2455155.4042	0.0019	0.0038	747	12.703	0.009	V	F.-J. Hambsch
2455175.3210	0.0020	–0.0378	784	—	—	—	M. Nobile
2455182.9060	0.0032	–0.0046	798	12.890	0.013	V	F.-J. Hambsch
2455189.3650	0.0040	–0.0186	810	12.867	0.015	V	F.-J. Hambsch
2455208.8035	0.0030	0.0010	846	13.014	0.008	V	F.-J. Hambsch
2455241.7199	0.0025	0.0130	907	12.963	0.010	V	F.-J. Hambsch

Table continued on next page

Table 4. List of measured maxima of NU Aur, cont.

Maximum HJD	*Error*	*O–C (day)*	*E*	*Magnitude*	*Error*	*Filter*	*Observer*
2455247.6585	0.0030	0.0180	918	12.862	0.009	V	F.-J. Hambsch
2455261.6812	0.0048	0.0159	944	12.898	0.009	V	F.-J. Hambsch
2455479.6006	0.0025	0.0115	1348	12.713	0.013	V	P. de Ponthière
2455481.7610	0.0026	0.0142	1352	12.741	0.010	V	F.-J. Hambsch
2455492.5516	0.0034	0.0165	1372	12.717	0.026	V	P. de Ponthière
2455511.9491	0.0020	–0.0050	1408	12.686	0.010	V	F.-J. Hambsch
2455528.6650	0.0024	–0.0110	1439	12.781	0.012	V	F.-J. Hambsch
2455531.8989	0.0031	–0.0135	1445	12.847	0.010	V	F.-J. Hambsch
2455538.9143	0.0040	–0.0105	1458	13.014	0.010	V	F.-J. Hambsch
2455540.5315	0.0075	–0.0116	1461	13.044	0.013	V	K. Menzies
2455542.6905	0.0041	–0.0103	1465	13.026	0.013	V	F.-J. Hambsch
2455543.7760	0.0048	–0.0036	1467	13.062	0.011	V	F.-J. Hambsch
2455545.9362	0.0042	–0.0010	1471	13.016	0.011	V	F.-J. Hambsch
2455548.6347	0.0036	0.0004	1476	13.066	0.008	V	R. Sabo
2455554.5716	0.0050	0.0037	1487	13.115	0.013	V	K. Menzies
2455555.6427	0.0035	–0.0040	1489	13.031	0.011	V	K. Menzies
2455571.3082	0.0060	0.0184	1518	13.057	0.016	V	P. de Ponthière
2455572.3921	0.0038	0.0235	1520	13.063	0.010	V	F.-J. Hambsch
2455575.6360	0.0060	0.0309	1526	13.045	0.001	V	F.-J. Hambsch
2455583.7160	0.0031	0.0197	1541	12.941	0.012	V	F.-J. Hambsch
2455589.6450	0.0047	0.0151	1552	12.919	0.012	V	K. Menzies
2455627.3941	0.0030	0.0051	1622	12.767	0.015	V	P. de Ponthière
2455627.3945	0.0016	0.0055	1622	12.775	0.006	V	F.-J. Hambsch
2455640.3375	0.0040	0.0025	1646	12.787	0.015	V	P. de Ponthière

Table 5. Comparison stars for VY CrB.

Identification *R.A. (2000)* *h m s*	*Dec. (2000)* *° ′ ″*	*B*	*V*	*B–V*	*DPP*	*Hambsch*	*Menzies*	*Sabo*
GSC 2576–1883								
16 06 45.0	+33 19 35.756	12.265	11.638	0.627	C1		C1	C1
GSC 2576–1372								
16 05 53.7	+33 20 17.166	14.97	13.71	1.26	C2	C1	C2	
GSC 2576–740								
16 06 13.7	+33 19 05.222	14.36	13.58	0.78	C3	C2	C3	C2
GSC 2576–1021								
16 06 05.5	+33 25 00.460	16.77	14.65	2.12	C4	C3	C4	

Table 6. List of measured maxima of VY CrB.

Maximum HJD	*Error*	*O–C (day)*	*E*	*Magnitude*	*Error*	*Filter*	*Observer*
2451615.5930	0.005	–0.0153	–7964	—	—	—	A. Paschke
2454215.5169	0.002	0.0089	–2348	—	—	—	J.-M. Llapasset
2454216.4421	0.002	0.0082	–2346	—	—	—	J.-M. Llapasset
2455302.4926	0.0013	–0.0105	0	13.480	0.009	C	P. de Ponthière
2455303.4196	0.0018	–0.0094	2	13.510	0.012	C	P. de Ponthière
2455309.4562	0.0031	0.0088	15	13.662	0.009	C	P. de Ponthière
2455310.3791	0.0023	0.0059	17	13.702	0.011	C	P. de Ponthière
2455321.4822	0.0021	–0.0017	41	13.548	0.008	C	P. de Ponthière
2455352.5027	0.0024	0.0015	108	13.602	0.008	C	P. de Ponthière
2455364.5240	0.0014	–0.0138	134	13.376	0.009	C	P. de Ponthière
2455370.5535	0.003	–0.0026	147	13.557	0.013	C	P. de Ponthière
2455371.4812	0.0024	–0.0008	149	13.570	0.009	C	P. de Ponthière
2455377.5180	0.008	0.0177	162	13.733	0.030	C	P. de Ponthière
2455378.4431	0.0053	0.0170	164	13.719	0.014	C	P. de Ponthière
2455384.4469	0.0033	0.0025	177	13.614	0.009	C	P. de Ponthière
2455390.4495	0.0016	–0.0132	190	13.352	0.009	C	P. de Ponthière
2455391.3773	0.0015	–0.0113	192	13.343	0.009	C	P. de Ponthière
2455396.4673	0.0016	–0.0137	203	13.343	0.007	C	P. de Ponthière
2455397.3939	0.0017	–0.0130	205	13.372	0.007	C	P. de Ponthière
2455410.3855	0.0048	0.0161	233	13.737	0.009	C	P. de Ponthière
2455441.3929	0.0029	0.0062	300	13.743	0.014	C	P. de Ponthière
2455461.2817	0.0015	–0.0116	343	13.347	0.008	C	P. de Ponthière
2455480.2825	0.0036	0.0084	384	13.676	0.009	C	P. de Ponthière
2455627.4899	0.003	–0.0007	702	13.555	0.010	C	P. de Ponthière
2455640.4717	0.007	0.0186	730	13.754	0.011	C	P. de Ponthière
2455622.8556	0.0054	–0.0056	692	13.316	0.058	V	K. Menzies
2455644.6183	0.0026	–0.0013	739	13.581	0.009	C	P. de Ponthière
2455645.5423	0.003	–0.0032	741	13.559	0.009	C	P. de Ponthière
2455646.4724	0.0041	0.0010	743	13.613	0.022	C	P. de Ponthière
2455602.9682	0.005	0.0137	649	13.717	0.015	V	F.-J. Hambsch
2455608.9772	0.005	0.0044	662	13.680	0.018	V	F.-J. Hambsch
2455609.9030	0.005	0.0043	664	13.661	0.025	V	F.-J. Hambsch
2455614.9834	0.0028	–0.0077	675	13.413	0.015	V	F.-J. Hambsch
2455615.9087	0.003	–0.0083	677	13.370	0.019	V	F.-J. Hambsch
2455622.8554	0.002	–0.0058	692	13.294	0.012	V	F.-J. Hambsch
2455629.8069	0.004	0.0016	707	13.582	0.018	V	F.-J. Hambsch
2455640.9245	0.007	0.0085	731	13.690	0.024	V	F.-J. Hambsch
2455646.9268	0.003	–0.0075	744	13.432	0.014	V	F.-J. Hambsch
2455647.8531	0.003	–0.0071	746	13.382	0.013	V	F.-J. Hambsch

Table continued on next page

Table 6. List of measured maxima of VY CrB, cont.

Maximum HJD	*Error*	*O–C (day)*	*E*	*Magnitude*	*Error*	*Filter*	*Observer*
2455653.8707	0.0022	–0.0078	759	13.276	0.013	V	F.-J. Hambsch
2455654.7969	0.0019	–0.0075	761	13.276	0.013	V	F.-J. Hambsch
2455660.8238	0.003	0.0011	774	13.545	0.014	V	F.-J. Hambsch
2455665.9194	0.0053	0.0043	785	13.695	0.018	V	F.-J. Hambsch
2455666.8510	0.0044	0.0101	787	13.715	0.020	V	F.-J. Hambsch
2455671.4845	0.0039	0.0141	797	13.748	0.011	C	P. de Ponthière
2455672.4003	0.0047	0.0040	799	13.769	0.012	C	P. de Ponthière
2455714.5166	0.0013	–0.0077	890	13.337	0.007	C	P. de Ponthière
2455715.4414	0.0014	–0.0088	892	13.325	0.007	C	P. de Ponthière
2455760.8215	0.003	0.0027	990	13.690	0.011	V	R. Sabo
2455739.5326	0.0041	0.0093	944	13.608	0.009	C	P. de Ponthière
2455775.6294	0.0025	–0.0036	1022	13.494	0.013	V	K. Menzies
2455784.4199	0.003	–0.0091	1041	13.367	0.010	C	P. de Ponthière

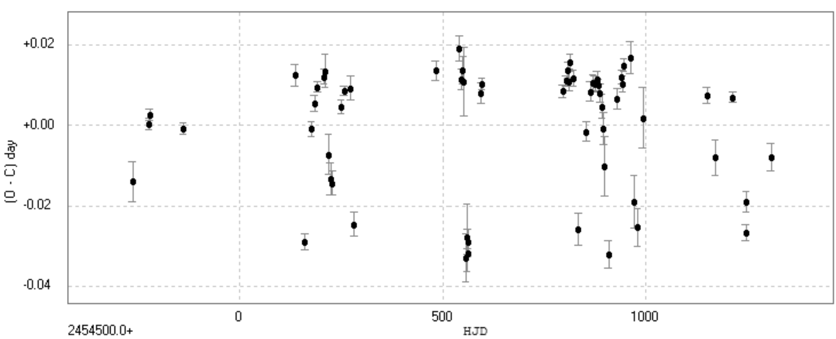

Figure 1. CX Lyr (O–C).

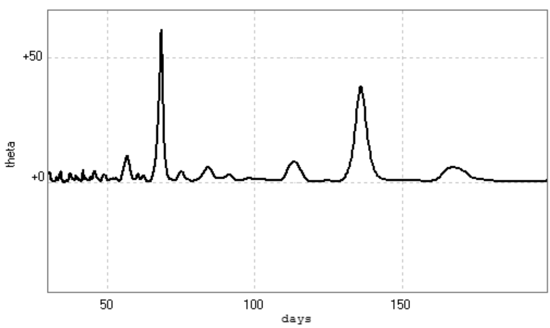

Figure 2. CX Lyr (O–C) periodogram.

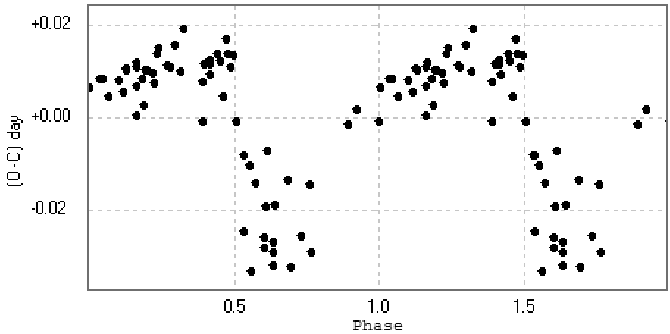

Figure 3a. CX Lyr (O–C) at maximum versus Blazhko phase.

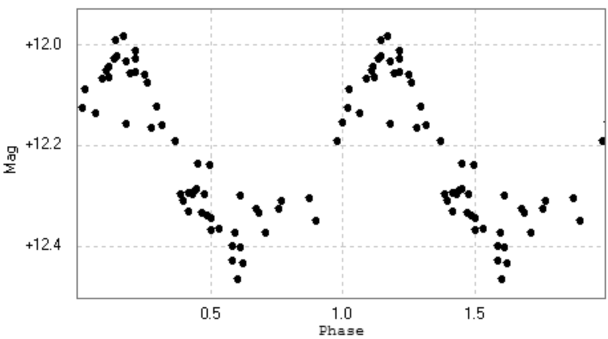

Figure 3b. CX Lyr magnitude at maximum versus Blazhko phase.

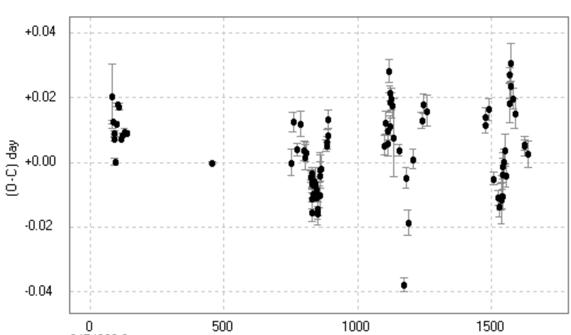

Figure 4. NU Aur (O–C).

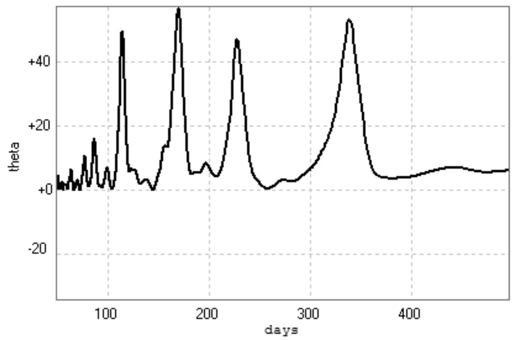

Figure 5a. NU Aur (O–C) periodogram.

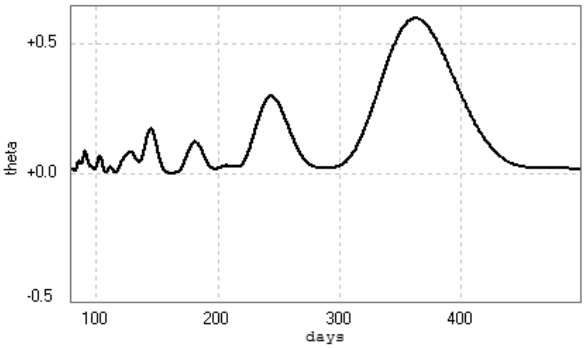

Figure 5b. NU Aur spectral window.

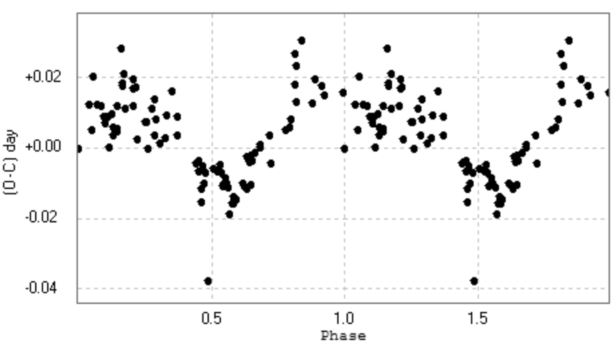

Figure 6a. NU Aur (O–C) at maximum versus Blazhko phase.

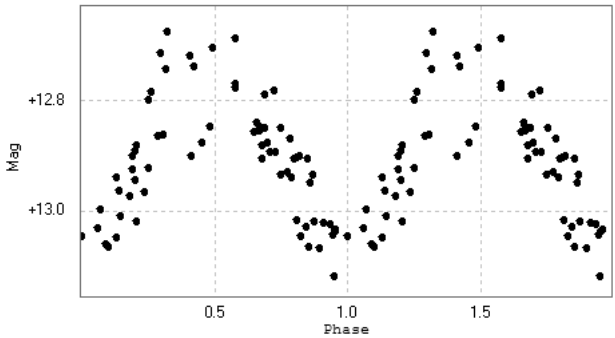

Figure 6b. NU Aur magnitude at maximum versus Blazhko phase.

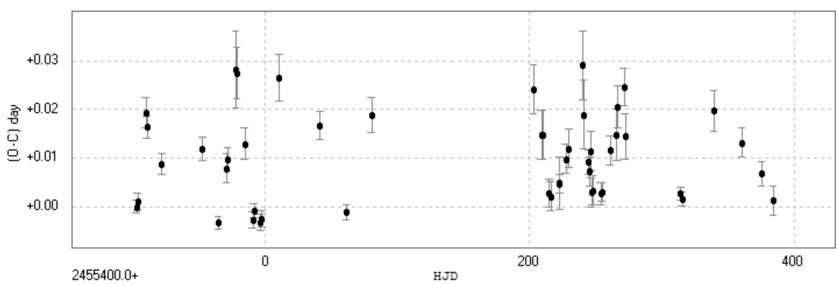

Figure 7. VY CrB (O–C).

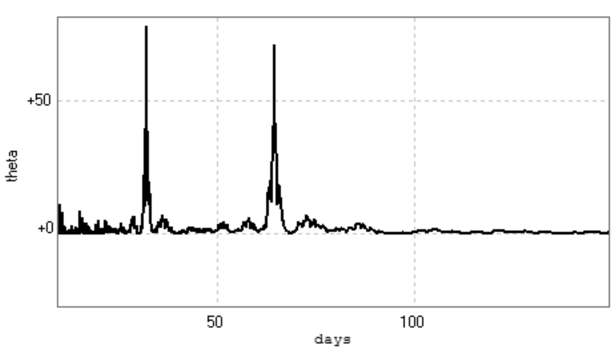

Figure 8. VY CrB (O–C) periodogram.

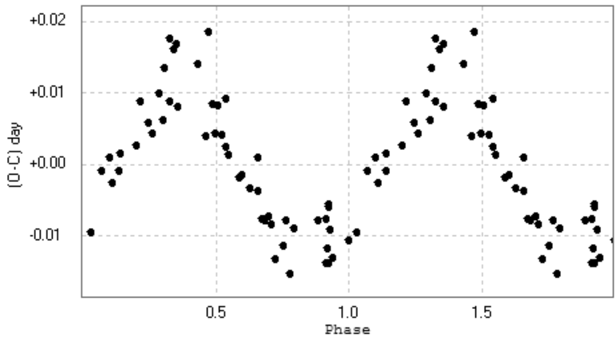

Figure 9a. VY CrB (O–C) at maximum versus Blazhko phase.

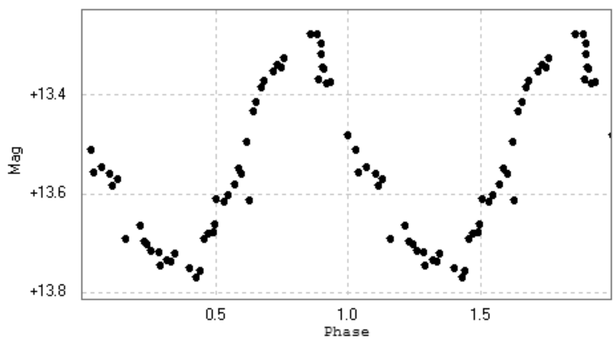

Figure 9b. VY CrB magnitude at maximum versus Blazhko phase.

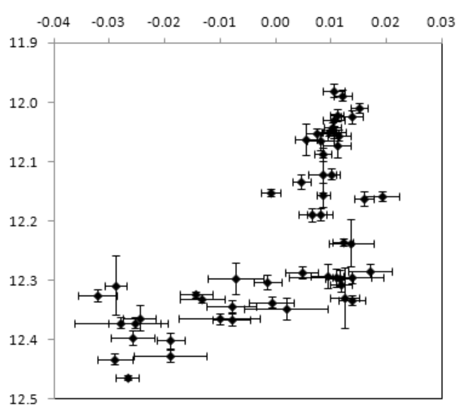

Figure 10a. CX Lyr magnitude at maximum versus (O–C) values.

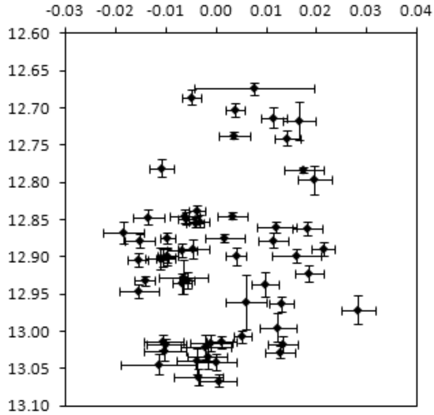

Figure 10b. NU Aur magnitude at maximum versus (O–C) values.

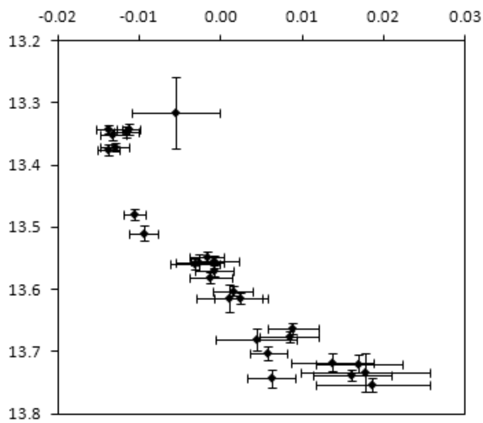

Figure 10c. VY CrB magnitude at maximum versus (O–C) values.