Multi-Longitude Observation Campaign of KV Cancri: an RR Lyrae Star with Irregular Blazhko Modulations

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Abstract We present the results of multi-longitude observations of KV Cancri, an RR Lyrae star showing an irregular Blazhko effect. With a pulsation period of 0.50208 day, the times of light curve maxima are delayed by 6 minutes per day. This daily delay regularly leads to long periods of time without maximum light curve observations for a given site. To cope with this observing time window problem, we have organized a multi-longitude observation campaign including a telescope of the AAVSONet. From the observed light curves, 92 pulsation maxima have been measured covering about six Blazhko periods. The Fourier analysis of magnitudes at maximum light has revealed a main Blazhko period of 77.6 days and also a secondary period of 40.5 days. A Fourier analysis of (O–C) values did not show the secondary Blazhko period. The frequency spectrum of the complete light curve, from a Fourier analysis and successive pre-whitening with PERIOD04, has shown triplet structures around the two Blazhko modulation frequencies but with slightly different periods (77.8 and 42.4 days). The second Blazhko frequency is statistically not a harmonic of the main Blazhko frequency. Besides the two Blazhko modulations KV Cnc presents other particularities like irregularities from Blazhko cycle to cycle and very fast magnitude variations which can reach a maximum of 2.5 magnitudes per hour over a period of 15 minutes. This campaign shows that regular observations by amateur astronomers remain important. Indeed, such a detailed characterization of the Blazhko effect could not be obtained from large-scale surveys, as cooperative long time-series observations are needed.

1. Introduction

The designation of KV Cnc appeared in the *General Catalogue of Variable Stars* (GCVS; Samus *et al.* 2011) with the 80th Name List of Variable Stars (Kazarovets *et al.* 2011), and previously this star was identified as GSC 1948-1733 and NSVS 7404884. From the Northern Sky Variability Survey data (Wozniak *et al.* 2004), Wils *et al.* (2006) have measured a pulsation period of 0.50202 day and they also provided an uncertain Blazhko period of 42 days.

The current data were gathered during 158 nights between January 2012 and May 2013. During this period of 480 days, a total of 32,280 magnitude measurements covering six Blazhko cycles were collected. The observations were made by the authors using 20-cm to 40-cm telescopes located in Bozeman (Montana), Cloudcroft (New Mexico), Framingham (Massachusetts), Lesve (Belgium), and Rhône-Alpes (France). The numbers of observations for the different locations are respectively 3367, 23614, 2621, 2610, and 92.

The comparison stars are given in Table 1. The star coordinates and magnitudes in B and V bands were obtained from the AAVSO's International Database (AID). Cloudcroft observations have been reduced with C2 as a magnitude reference and C4 as a check star. The other observations have used C1 as a magnitude reference and C3 and C4 as check stars.

Since measurements were performed with V filters only, it was impossible to transform the measurements to the standard system. However, thanks to simultaneous maximum measurements from the instruments in Cloudcroft and Bozeman it has been possible to take account of the magnitude offset due to the color differences of the magnitude reference stars. This offset has been applied to observations based on C1 as reference. Dark and flat field corrections were performed with MAXIMDL software (Diffraction Limited 2004), and aperture photometry was performed using LESVEPHOTOMETRY (de Ponthière 2010), a custom software which also evaluates the SNR and estimates magnitude errors.

Table 1. Comparison stars.

Identification	*R. A. (2000)* h m s	*Dec. (2000)* ° ′ ″	*B*	*V*	*B–V*	
GSC 1948-1556	08 40 05.47	+27 39 12.1	12.526	11.998	0.528	C1
GSC 1948-1451	08 40 09.30	+27 41 19.4	13.627	12.946	0.681	C2
GSC 1948-1631	08 40 34.19	+27 47 50.0	13.972	13.204	0.768	C3
GSC 1948-1548	08 40 00.87	+27 42 35.9	14.110	13.543	0.567	C4

Table 2. List of measured maxima of KV Cnc.

Maximum HJD	Error	O–C (day)	E	Magnitude (V)	Error	Location*
2455943.4189	0.0026	0.0553	–184	12.023	0.01	2
2455944.4178	0.0030	0.0500	–182	12.007	0.01	2
2455960.4523	0.0012	0.0170	–150	11.663	0.01	2
2455962.4642	0.0018	0.0205	–146	11.709	0.012	2
2455967.5064	0.0021	0.0416	–136	11.930	0.003	3
2455970.5282	0.0026	0.0507	–130	11.990	0.005	3
2455971.5335	0.0035	0.0518	–128	11.990	0.004	3
2455978.5639	0.0016	0.0526	–114	12.144	0.004	3
2455984.5914	0.0026	0.0548	–102	12.220	0.004	3
2455989.6193	0.0053	0.0616	–92	12.278	0.005	4
2455992.6310	0.0037	0.0607	–86	12.276	0.006	3
2455996.6553	0.0038	0.0681	–78	12.288	0.004	5
2455997.6525	0.0039	0.0611	–76	12.249	0.005	3
2455998.6595	0.0047	0.0638	–74	12.285	0.005	4
2456000.6733	0.0077	0.0692	–70	12.255	0.005	4
2456004.6854	0.0043	0.0644	–62	12.255	0.005	3
2456008.7018	0.0034	0.0639	–54	12.245	0.005	3
2456008.7032	0.0029	0.0653	–54	12.243	0.004	5
2456008.7041	0.0043	0.0662	–54	12.243	0.005	4
2456009.7026	0.0078	0.0605	–52	12.277	0.005	4
2456009.7085	0.0040	0.0664	–52	12.277	0.004	5
2456011.7174	0.0065	0.0669	–48	12.245	0.005	4
2456011.7219	0.0035	0.0714	–48	12.243	0.004	5
2456013.7404	0.0043	0.0814	–44	12.250	0.005	4
2456015.7505	0.0039	0.0831	–40	12.204	0.005	4
2456016.7472	0.0030	0.0756	–38	12.185	0.006	4
2456021.7383	0.0017	0.0456	–28	11.999	0.005	5
2456023.7350	0.0018	0.0338	–24	11.947	0.007	4
2456028.7337	0.0007	0.0114	–14	11.703	0.004	5
2456029.7368	0.0013	0.0103	–12	11.696	0.005	4
2456030.7368	0.0010	0.0061	–10	11.617	0.019	5
2456031.7412	0.0018	0.0063	–8	11.590	0.039	5
2456033.7459	0.0007	0.0025	–4	11.541	0.006	4
2456034.7501	0.0020	0.0025	–2	11.545	0.006	4
2456035.7518	0.0030	0.0000	0	11.524	0.005	4
2456038.7683	0.0006	0.0038	6	11.614	0.006	4
2456039.7718	0.0005	0.0031	8	11.622	0.004	5
2456039.7740	0.0006	0.0053	8	11.615	0.006	4
2456055.3917	0.0026	0.0576	39	12.106	0.012	2

Table continued on following pages

Table 2. List of measured maxima of KV Cnc, cont.

Maximum HJD	*Error*	*O–C (day)*	E	*Magnitude (V)*	*Error*	*Location**
2456061.4163	0.0052	0.0569	51	12.165	0.016	2
2456202.9511	0.0012	–0.0033	333	11.862	0.006	4
2456205.9689	0.0011	0.0018	339	11.969	0.005	4
2456209.0013	0.0040	0.0215	345	12.051	0.011	5
2456248.6817	0.0039	0.0353	424	12.048	0.011	2
2456254.6918	0.0015	0.0200	436	11.861	0.005	3
2456256.6971	0.0018	0.0169	440	11.815	0.004	3
2456265.7291	0.0013	0.0109	458	11.777	0.004	3
2456268.7406	0.0016	0.0098	464	11.777	0.004	3
2456276.7683	0.0012	0.0037	480	11.724	0.016	3
2456279.7819	0.0015	0.0046	486	11.730	0.013	4
2456280.7878	0.0004	0.0063	488	11.767	0.004	5
2456281.7901	0.0017	0.0044	490	11.740	0.014	4
2456282.7959	0.0013	0.0060	492	11.778	0.01	4
2456287.8229	0.0015	0.0119	502	11.924	0.004	3
2456290.8423	0.0023	0.0186	508	11.960	0.014	4
2456292.8584	0.0031	0.0263	512	12.062	0.006	3
2456294.8715	0.0026	0.0309	516	12.109	0.005	3
2456295.8814	0.0023	0.0366	518	12.106	0.005	3
2456297.9004	0.0045	0.0472	522	12.158	0.007	5
2456300.9255	0.0029	0.0596	528	12.202	0.007	3
2456303.4492	0.0041	0.0728	533	12.168	0.011	2
2456308.9646	0.0043	0.0650	544	12.125	0.019	4
2456308.9684	0.0096	0.0688	544	12.146	0.073	5
2456310.9718	0.0034	0.0637	548	12.106	0.01	4
2456311.9694	0.0030	0.0571	550	12.117	0.011	5
2456311.9742	0.0042	0.0619	550	12.101	0.017	4
2456312.9772	0.0068	0.0607	552	12.079	0.013	4
2456313.9725	0.0027	0.0518	554	12.064	0.011	4
2456314.9747	0.0028	0.0497	556	12.077	0.011	5
2456315.9759	0.0023	0.0467	558	12.028	0.011	4
2456323.4865	0.0041	0.0257	573	11.993	0.02	2
2456323.9876	0.0035	0.0247	574	11.980	0.017	4
2456328.4990	0.0028	0.0171	583	12.007	0.008	3
2456330.5028	0.0016	0.0124	587	11.975	0.004	3
2456334.5124	0.0017	0.0051	595	11.937	0.004	3
2456340.5428	0.0015	0.0102	607	12.000	0.008	1
2456343.5518	0.0015	0.0066	613	11.984	0.009	1
2456351.5974	0.0035	0.0184	629	11.734	0.019	4

Table continued on next page

Table 2. List of measured maxima of KV Cnc, cont.

Maximum HJD	*Error*	*O–C (day)*	E	*Magnitude (V)*	*Error*	*Location**
2456352.6018	0.0036	0.0186	631	11.726	0.022	4
2456353.6024	0.0021	0.0150	633	11.682	0.023	4
2456354.6071	0.0020	0.0154	635	11.679	0.016	4
2456358.6164	0.0019	0.0079	643	11.645	0.016	4
2456363.6383	0.0018	0.0087	653	11.825	0.011	5
2456363.6391	0.0025	0.0095	653	11.784	0.024	4
2456369.6638	0.0015	0.0088	665	12.022	0.004	3
2456374.7017	0.0026	0.0256	675	12.188	0.006	3
2456376.7208	0.0073	0.0363	679	12.257	0.026	5
2456392.8007	0.0072	0.0487	711	12.048	0.014	5
2456400.8163	0.0015	0.0305	727	11.944	0.007	5
2456403.3272	0.0024	0.0309	732	11.868	0.012	2
2456407.3363	0.0025	0.0231	740	11.885	0.01	2
2456418.3574	0.0037	–0.0022	762	11.970	0.012	2

Locations: 1) Rhône–Alpes (France); 2) Lesve (Belgium); 3) Framingham (MA); 4) Cloudcroft (NM); 5) Bozeman (MT)

2. Light curve maxima analysis

The times of maxima of the light curves have been evaluated with custom software (de Ponthière 2010) fitting the light curve with a smoothing spline function (Reinsch 1967). Table 2 provides the list of ninety-two observed maxima and Figures 1a and 1b show the (O–C) and M_{max} (Magnitude at Maximum) values. From an inspection of the (O–C) and M_{max} graphs the Blazhko effect is obviously irregular. The shape of the (O–C) curve during Blazhko cycles does not repeat. During the first observation season, between the dates HJD 2455970 and 2456011, the (O–C) values vary more or less linearly before an abrupt fall. This (O–C) curve variation does not repeat during the next season. The M_{max} graph suggests the presence of a second modulation frequency. The Blazhko effect is itself apparently modulated by a lower frequency component.

A linear regression of all available (O–C) values has provided a pulsation period of 0.5020802 d (1.99171 d^{-1}). The (O–C) values have been re-evaluated with this new pulsation period and the pulsation ephemeris origin has been set to the highest recorded brightness maximum: HJD 2456035.7518. The new derived pulsation elements are:

$$HJD_{Pulsation} = (2456035.7518 \pm 0.0030) + (0.5020802 \pm 0.0000078)\, E_{Pulsation} \quad (1)$$

The derived pulsation period is in good agreement with the value of 0.50202d

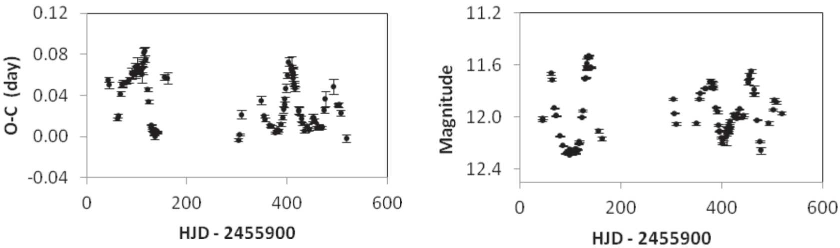

Figure 1. KV Cnc O–C (days, on left) and M_{max} magnitude at maximum (on right).

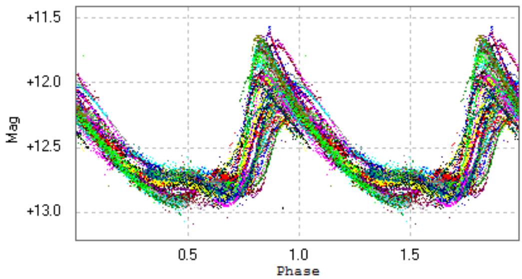

Figure 2. KV Cnc light curve folded with pulsation period of 0.50202 d.

Table 3. Blazhko spectral components from light curve maxima.

From (O–C) values						
Frequency (cycle/days)	*σ(d^{-1})*	*Period (days)*	*σ(d)*	*Amplitude (days)*	*ϕ (cycle)*	*SNR*
0.01298	9 10^{-5}	77.02	0.54	0.028	0.926	10.4
From M_{max}						
Frequency (cycle/days)	*σ(d^{-1})*	*Period (days)*	*σ(d)*	*Amplitude (V mag.)*	*ϕ (cycle)*	*SNR*
0.01289	4 10^{-5}	77.57	0.25	0.245	0.993	22.6
0.02471	9 10^{-5}	40.48	0.14	0.119	0.398	11.0

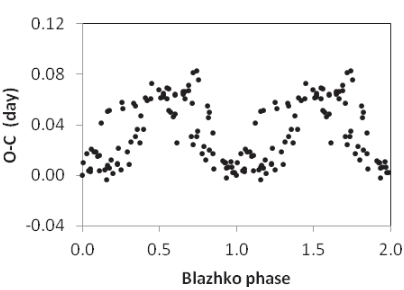

Figure 3. KV Cnc O–C based on Blazhko period of 77.57 days.

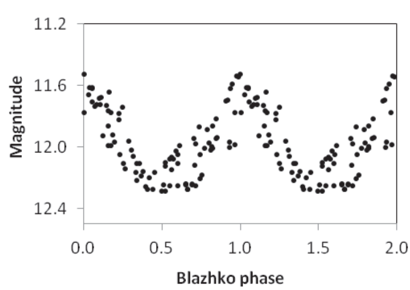

Figure 4. KV Cnc M_{max} based on Blazhko period of 77.57 days.

published by Wils *et al.* (2006). The folded light curve on this pulsation period is shown in Figure 2.

To determine the Blazhko period, Fourier analyses and sine-wave fittings of the (O–C) values and M_{max} (Magnitude at Maximum) values were performed with PERIOD04 (Lenz and Breger 2005). These analyses were limited to the first two frequency components and are given in Table 3. The frequency uncertainties have been evaluated from the Monte Carlo simulation module of PERIOD04. The obtained periods (77.02 ± 0.54 and 77.57 ± 0.25 days) for the main Blazhko effect agree within the errors. Another secondary Blazhko period of 40.48 days is found in the spectrum of M_{max} which is close to the uncertain value of 42 days provided by Wils *et al.* (2006). They probably did not detect the main Blazhko period from the Northern Sky Variability Survey due to the scarcity of the data.

On this basis the best Blazhko ephemeris is

$$HJD_{Blazhko} = 2456035.7518 + (77.57 \pm 0.25)\, E_{Blazhko} \qquad (2)$$

where the origin has been selected as the epoch of the highest recorded maximum.

The (O–C) and M_{max} curves folded with the Blazhko period of 77.02 days are given in Figures 3 and 4. In these diagrams, the scatter of the data is mainly due to the second Blazhko frequency and the irregular behavior from Blazhko cycle to cycle. An attempt at pre-whitening with the secondary Blazhko frequency has not significantly reduced the scatter in the folded (O–C) and M_{max} graphs. Due to an irregular Blazhko effect, the two detected frequency components are not able to precisely model the (O–C) and M_{max} data series.

3. Frequency spectrum analysis of the light curve

In the preceding paragraph, describing the M_{max} analysis, a primary pulsation and two Blazhko frequencies have been identified. It will be shown that these modulating frequencies are clearly present in the spectrum of the complete light curve.

The spectrum of a signal modulated in amplitude and phase is characterized by a pattern of peaks called multiplets at the positions $kf_0 \pm nf_B$ with k and n being integers corresponding respectively to the harmonic and multiplet orders. The frequencies, amplitudes and phases of the multiplets have been obtained with PERIOD04 by performing a succession of Fourier analyses, pre-whitenings and sine-wave fittings. Only the harmonic and multiplet components having a signal to noise ratio (SNR) greater than 4 have been retained as significant signals. Table 5 provides the complete list of Fourier components with their amplitudes, phases, and uncertainties. Besides the pulsation frequency f_0 and harmonics nf_0, two series of triplets, $nf_0 \pm f_B$ and $nf_0 \pm f_{B2}$, based on the principal and secondary Blazhko frequencies f_B and f_{B2} have been found. The Blazhko frequencies and corresponding periods are tabulated in Table 4 with their

Table 4. Blazhko frequencies and periods derived from triplets.

Component	*Derived from*	*Frequency* (d^{-1})	$\sigma(d^{-1})$	*Period (d)*	$\sigma(d)$
f_0	—	1.991689	1.7×10^{-6}	0.5020864	4×10^{-7}
f_B	$f_0 + f_B$	0.012853	8×10^{-6}	77.80	0.05
f_{B2}	$f_0 + f_{B2}$	0.023593	16×10^{-6}	42.39	0.03

Table 5. Multi–frequency fit results.

Component	$f(d^{-1})$	$\sigma(f)$	A_i *(mag.)*	$\sigma(A_i)$	Φ_i *(cycle)*	$\sigma(\Phi_i)$	*SNR*
f_0	1.991689	1.7×10^{-6}	0.3646	0.0008	0.2022	0.0005	118.5
$2\ f_0$	3.983378	—	0.1298	0.0012	0.7825	0.0013	46.0
$3\ f_0$	5.975067	—	0.0818	0.0011	0.4018	0.0018	29.8
$4\ f_0$	7.966757	—	0.0400	0.0009	0.0400	0.0046	16.4
$5\ f_0$	9.958446	—	0.0268	0.0010	0.6656	0.0065	13.5
$6\ f_0$	11.950135	—	0.0203	0.0011	0.3226	0.0082	11.7
$7\ f_0$	13.941824	—	0.0110	0.0009	0.0354	0.0119	7.0
$8\ f_0$	15.933513		0.0055	0.0008	0.7105	0.0230	3.9
f_0+f_B	2.004542	8×10^{-6}	0.0582	0.0011	0.5060	0.0031	18.9
f_0-f_B	1.978836	—	0.0759	0.0009	0.0580	0.0017	24.7
$2\ f_0+f_B$	3.996231	—	0.0482	0.0010	0.1499	0.0040	17.1
$2\ f_0-f_B$	3.970525	—	0.0419	0.0011	0.6413	0.0044	14.8
$3\ f_0+f_B$	5.987920	—	0.0303	0.0011	0.7451	0.0060	11.0
$3\ f_0-f_B$	5.962215	—	0.0214	0.0010	0.2807	0.0076	7.8
$4\ f_0+f_B$	7.979609	—	0.0216	0.0011	0.3640	0.0076	8.9
$4\ f_0-f_B$	7.953904	—	0.0244	0.0011	0.8420	0.0071	9.9
$5\ f_0+f_B$	9.971299	—	0.0130	0.0009	0.9890	0.0116	6.6
$5\ f_0-f_B$	9.945593	—	0.0211	0.0011	0.5055	0.0079	10.7
$6\ f_0+f_B$	11.962988	—	0.0096	0.0008	0.5410	0.0144	5.5
$6\ f_0-f_B$	11.937282	—	0.0150	0.0011	0.1600	0.0119	8.7
$7\ f_0+f_B$	13.954677	—	0.0096	0.0009	0.1890	0.0115	6.1
$7\ f_0\ -f_B$	13.92897	—	0.0089	0.0007	0.8373	0.0154	5.7
f_0+f_B	2.015282	16×10^{-6}	0.0394	0.0008	0.2681	0.0034	12.8
f_0-f_B	1.968096	—	0.0258	0.0009	0.7453	0.0066	8.4
$2\ f_0+f_B$	4.006971	—	0.0352	0.0009	0.8826	0.0042	12.5
$2\ f_0-f_B$	3.959785	—	0.0124	0.0010	0.1666	0.0113	4.3
$3\ f_0+f_B$	5.998660	—	0.0174	0.0010	0.5395	0.0084	6.4
$3\ f_0-f_B$	5.951475	—	0.0154	0.0009	0.7617	0.0102	5.6

Table 6. KV Cnc harmonic, triplet amplitudes, ratios, and asymmetry parameters.

i	A_i/A_1	A_i^+/A_1	A_i^-/A_1	R_i	Q_i	$R_i\,(f_{B2})$	$Q_i\,(f_{B2})$
1	1.00	0.16	0.21	0.77	–0.13	1.53	0.21
2	0.36	0.13	0.11	1.15	0.07	2.85	0.48
3	0.22	0.08	0.06	1.42	0.17	1.13	0.06
4	0.11	0.06	0.07	0.89	–0.06	—	—
5	0.07	0.04	0.06	0.62	–0.24	—	—
6	0.06	0.03	0.04	0.64	–0.22	—	—
7	0.03	0.03	0.02	1.08	0.04	—	—
8	0.02	—	—	—	—	—	—

uncertainties. These Blazhko periods are close to the values obtained with M_{max} analysis given in Table 3.

During the sine-wave fitting, the fundamental frequency f_0 and largest triplets $f_0 + f_B$ and $f_0 + f_{B2}$ have been left unconstrained and the other frequencies have been entered as combinations of these three frequencies. The uncertainties of frequencies, amplitudes, and phases have been estimated by Monte Carlo simulations. The amplitude and phase uncertainties have been multiplied by a factor of two as it is known that the Monte Carlo simulations underestimate these uncertainties (Kolenberg *et al.* 2009). The two Blazhko modulation frequencies f_B (0.012853) and f_{B2} (0.023593) are statistically ($\sigma = 16 \times 10^{-6}$) not in resonance, provided that the n:m resonance ratios with n or m greater than 10 are not taken into account. For CZ Lacertae (Sódor *et al.* 2011) and V784 Ophiuchi (de Ponthière *et al.* 2013) 5:4 and 5:6 resonance ratios have been found.

Table 6 lists for each harmonic the amplitude ratios A_i/A_1 and the ratios usually used to characterize the Blazhko effect, that is, A_i^+/A_1 ; A_i^-/A_1 ; $R_i = A_i^+/A_i^-$; and asymmetries $Q_i = (A_i^+ - A_i^-)/(A_i^+ + A_i^-)$. In the present case the side lobe A_i^- is larger than A_i^+ which leads to a negative value (–0.13) for the Q_i asymmetry ratio. It is not unusual but for the majority of the Blazhko stars, this asymmetry ratio is positive (see figure 10 of Alcock *et al.* 2003). The R_i and Q_i ratios for triplets around the secondary Blazhko frequency f_{B2} are also given in Table 6. The asymmetry ratios Q_i for f_{B2} are positive.

4. Light curve variations over Blazhko cycle

Subdividing the data set into temporal subsets is a classical method to visualize and analyze the light curve variations over the Blazhko cycle. Ten temporal subsets corresponding to the different Blazhko phase intervals Ψ_i (i = 0, 9) have been created using the epoch of the highest recorded maximum (2456035.7518) as the origin of the first subset. The folded light curves for the ten subsets are presented in Figure 5. Over the subsets, the number of data points varies between 1916 and 5678. Other than a lack of coverage in two

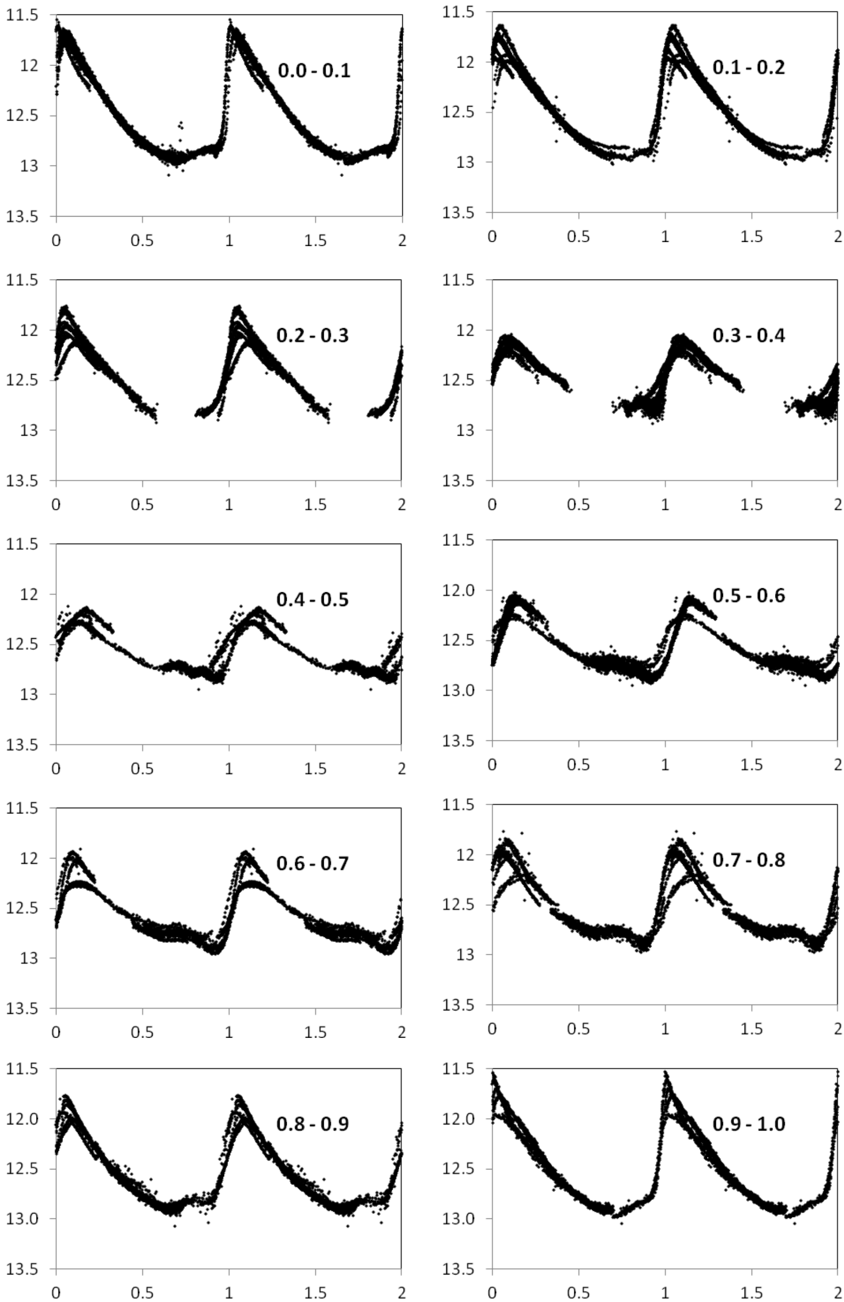

Figure 5. KV Cnc light curves for different temporal subsets (magnitude vs. pulsation phase) based on a Blazhko period of 77.80 days.

Table 7. KV Cnc Fourier coefficients over Blazhko cycle based on period of 77.80 days.

Ψ (cycle)	A_1 (mag.)	A_2 (mag.)	A_3 (mag.)	A_4 (mag.)	Φ_1 (rad.)	Φ_{21} (rad.)	Φ_{31} (rad.)	Φ_{41} (rad.)
0.0–0.1	0.503	0.190	0.117	0.082	1.410	2.315	4.860	1.300
0.1–0.2	0.467	0.187	0.133	0.082	1.356	2.430	5.207	1.953
0.2–0.3	0.420	0.090	0.096	0.076	1.142	2.487	4.463	1.278
0.3–0.4	0.215	0.201	0.068	0.093	0.398	4.022	4.811	3.762
0.4–0.5	0.244	0.099	0.036	0.021	1.206	2.213	5.651	1.804
0.5–0.6	0.296	0.133	0.068	0.033	1.148	2.308	5.326	1.332
0.6–0.7	0.279	0.134	0.080	0.039	0.996	2.315	5.350	1.856
0.7–0.8	0.345	0.156	0.094	0.044	0.975	2.216	5.103	1.596
0.8–0.9	0.402	0.141	0.089	0.048	1.309	2.230	4.587	0.987
0.9–1.0	0.482	0.191	0.115	0.075	1.409	2.405	5.124	1.666

subsets when the light curve is at its minimum, the data points are relatively well distributed.

Despite the subdivision over the Blazhko cycle, a scatter still remains on the light curves; this fact has been already pointed out in the light curve maxima analysis. A visual inspection of the light curves in different subsets reveals that the light curve slope is at its steepest value in the two subsets from Blazhko phases 0.9 to 0.1, that is, when the peak to peak magnitude variations and magnitude at maximum are at their maximal values. An astonishing slope of 2.9 magnitudes per hour has been recorded. Generally the RR Lyrae light curves present a bump just before the minimum. For KV Cnc, in the two subsets from 0.9 to 0.1, the bump is replaced by a slightly increasing slope.

Fourier analyses and Least-Square fittings have been performed on the different temporal subsets. For the fundamental and the first four harmonics the amplitudes A_i and the epoch-independent phase differences ($\Phi_{k1} = \Phi_k - k\Phi_{k1}$) are given in Table 7 and plotted in Figure 6. The amplitudes have large uncertainties for the subsets 0.2–0.3 and 0.3–0.4. This is due to the lack of coverage at light curve minimum as shown in Figure 5. These amplitude uncertainties probably impact the epoch-independent phase differences especially in the subset 0.3–0.4 where the phase differences seem to be dubious. As expected the A_1 amplitudes of the fundamental frequency have lower values for Blazhko phases 0.4 to 0.7, that is, when the light curve amplitude variations on the pulsation are weaker.

5. Conclusions

Blazhko modulations have been detected by measurements of (O–C) values and magnitude of light curve maxima and confirmed by complete light curve Fourier analysis. The Blazhko periods obtained by the complete light curve

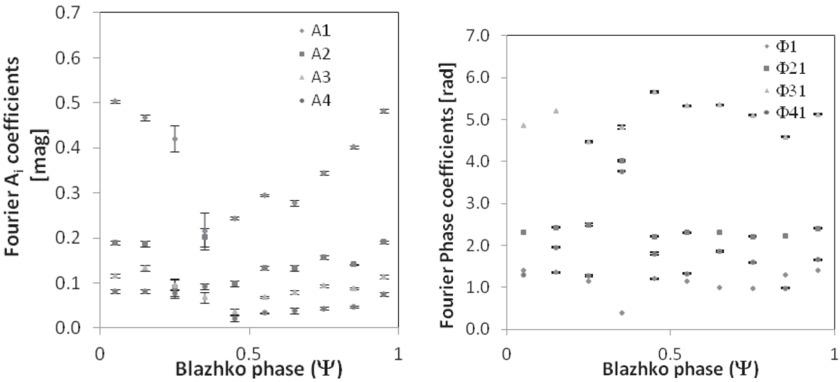

Figure 6. (left): KV Cnc Fourier A_i amplitude (mag.) for the ten temporal subsets based on a Blazhko period of 77.80 days. (right): Fourier Φ_1 and Φk_i phase (rad.) for the ten temporal subsets based on a Blazhko period of 77.80 days.

analysis are reported as their period uncertainties are lower. The main Blazhko period ($1/f_B$) is 77.80 ± 0.05 days. The secondary Blazhko period ($1/f_{B2}$) is 42.39 ± 0.03 days. These two Blazhko modulations are not in resonance. Regular and coordinated multi-longitude observations by amateurs have been needed to cope with the problem of observation time windows created by the pulsation period of 0.50208 day. Amateur astronomers observing RR Lyrae stars have the tendency to restrict their observations near the maximum of light curve which is indeed important. However, the problems encountered in the Fourier analysis in Blazhko subsets were due to a lack of data during the minimum part of the pulsation cycle. Observers are encouraged to also image during pulsation phases other than near the maximum.

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References

Alcock, C., *et al.* 2003, *Astrophys. J.*, 598, 597.

de Ponthière, P. 2010, LESVEPHOTOMETRY, automatic photometry software (http://www.dppobservatory.net).

de Ponthière, P., *et al.* 2013, *J. Amer. Assoc. Var. Star Obs.*, **41**, 214.

Diffraction Limited. 2004, MAXIMDL image processing software (http://www.cyanogen.com).

Kazarovets, E. V., *et al.* 2011, *Inf. Bull. Var. Stars,* No. 6008, 1.

Kolenberg, K., *et al.* 2009, *Mon. Not. Roy. Astron. Soc.*, **396**, 263.

Lenz, P., and Breger, M. 2005, *Commun. Asteroseismology*, **146**, 53.

Reinsch, C. H. 1967, *Numer. Math.*, **10**, 177.

Samus, N. N., *et al.* 2011, *General Catalogue of Variable Stars* (GCVS database, Version 2011 January, http://www.sai.msu.su/gcvs/gcvs/index.htm).

Sódor, Á. *et al.* 2011, *Mon. Not. Roy. Astron. Soc.*, **411**, 1585.

Wils, P., Lloyd, C., and Bernhard, K. 2006, *Mon. Not. Roy. Astron. Soc.*, **368**, 1757.

Wozniak, P., *et al.* 2004, *Astron. J.*, **127**, 2436.