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FIRST RESULT OF THE CZECH RR LYRAE STARS OBSERVATION PROJECT - A NEW BLAZHKO STAR CN Cam

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We introduce a new project which attempts to provide precise, filtered measurements of RR Lyraes, which were not observed by automatic surveys (or the survey data were of bad quality), and which were not studied in detail, or are somehow interesting. The basic goal is to obtain well-covered light curves to determine ephemerides, periods, light curve characteristics (amplitude, rising time) and finally to obtain Fourier parameters to estimate the basic physical parameters.

We founded a project now called *The Czech RR Lyrae Stars Observation Project* (hereafter CRRLSOP), which cooperates with amateur observers from the Variable Star and Exoplanet Section of Czech Astronomical Society.[1] In 2012 our group comprised five members and we hope that this number will increase in years to come. A similar, but professional survey, dealing with RR Lyraes is under way in Hungary – *The Konkoly Blazhko Survey* (Sódor 2007). They use only one telescope contrary to our project that using many telescopes. Another project focused on RR Lyraes cooperating with amateurs is *GEOS RR Lyr database* (Boninsegna et al. 2002). The GEOS database deals with maxima timings of RR Lyraes.

To be able to get data of high quality, CRRLSOP focuses on bright RR Lyraes with V< 12 mag at maximum light. This value is chosen to suit the telescopes that amateurs use, which are typically of the diameter between 20 and 30 cm. Another restriction is imposed by the location of the Czech Republic. We choose targets with a declination of typically more than 20°, which are easily observable for a long time during the year.

Each target is carefully selected to suit an observer's equipment and taking the observer's time constrains into account. Observers are briefed in detail about exposure times and about field of view selection. All the observations are subsequently discussed. Each star is monitored by only one observer to avoid merging data from different devices. We also put emphasis on the comparison star selection.

All the measurements gathered by observers are processed in the same way using aperture photometry software CMunipack.[2] The structure of the observations is as follows: stars which are expected to have a stable light curve are observed two nights in a row

[1] http://var2.astro.cz/EN/
[2] http://c-munipack.sourceforge.net/

followed by observations taken after one week, a few weeks and finally after a few months to verify the stability of the stellar pulsation. In the case of Blazhko stars, the objects are monitored as often as possible to cover all Blazhko phases. The time schedule of observations is not strictly given, because of weather or other unpredictable reasons.

CN Cam (= NSV 5256 = SAO1900 = BD+82 338 = GSC 04556-00251, J2000 $11^{h}36^{m}11\overset{s}{.}8$, $+81°17'37\overset{\prime\prime}{.}1$), found to be a variable by Strohmeier & Knigge (1961), was first proposed to be an eclipsing binary. Based on a 12-night study, Campos-Cucarella et al. (1996) (hereafter CC96) classified CN Cam as an RRab star and established its period as 0.6214(1) d. Kinman et al. (2007) (hereafter K07) improved the period to 0.621445(2) d and determined the amplitude of the light changes to be 0.36 mag in V and 0.49 mag in B, CC96 gives 0.350(5) mag in V and 0.474(4) mag in B. K07 also estimated the metallicity of CN Cam using Fourier coefficients, amplitude in V and rise-time (methods listed in Sandage (2004)). The values of metallicity that K07 obtained were around [Fe/H] = −1.1. K07 found the distance of CN Cam as 594 pc.

One of the most recent observations was performed by Maintz (2012). Between the years 2006 and 2012 she obtained seven maxima timings and improved the value of the period to 0.6214465(3) d. The Blazhko effect was not noted in any of these works.

We observed CN Cam in BVR_cI_c passbands during 20 nights from the end of January till the end of June 2012. We obtained between 1340 and 1630 points in each filter. Observations were carried out using the 20-cm Newtonian telescope of the Observatory and Planetarium of Johann Palisa in Ostrava equipped with an SBIG-ST8 XME camera. The data were reduced in the classic way and were transformed into the standard Johnson-Cousins magnitudes using stars in Landolt fields (Landolt 1992).

Similarly as CC96 and K07, we used GSC 04556-00278 (= SAO1899 = BD+82 337) as a comparison star and GSC 04556-00278 as a check star. According to the $J = 9.453(23)$ and $K = 9.248(22)$ magnitudes of the comparison taken from 2MASS All-Sky Catalog of Point Sources (Cutri et al. 2003) we got Johnson-Cousins magnitudes of the comparison via the relations in Warner (2007) (see Table 1). Our $V = 10.24(5)$ magnitude of the comparison fall between the magnitudes given by CC96 and K07 (10.3 and 10.201(3) mag, respectively).

Table 1. Observation log and magnitude of the comparison star in different passbands.

Nights	Time-span [d]	B	V	R_c	I_c
20	186	1341	1498	1495	1629
brightness of the comparison star [mag]		10.62(9)	10.24(5)	10.01(5)	9.77(5)

After performing the period analysis with Period04 (Lenz & Breger 2005) we found the following ephemeris:

$$\mathrm{HJD\ T_{max}} = 2455959.4707(36) + 0.621446(3)\mathrm{E_{puls}}. \quad (1)$$

The time of the extremum is based on the V data and it was determined using lesvephotometry software (de Ponthire 2010) by fitting the light curve with a smoothing spline function (Reinsch 1967). The value of the period is within the error bars in agreement with the period determined by Maintz (2012).

Frequency analysis with Period04 revealed additional frequency peaks on the right-hand side of the basic pulsation frequency ($f_0 = 1.6091504(73)$ c/d) and its harmonics (kf_0, where $k = 1, 2, 3...$). Such a frequency structure is one of the most noticeable manifestations of the Blazhko effect. In total we identified peaks related to the basic pulsation frequency up to $k = 8$ and four peaks corresponding to the modulation frequency ($kf_0 + f_B$ up to $k = 4$). The spacings of the side peaks were not equidistant, but they were slightly decreasing with rising k. The side peak with the highest amplitude was $f_0 + f_B = 1.629877(61)$ c/d. Therefore we give the first rough estimation of the Blazhko period of CN Cam $P_{\rm BL} = 48.25(14)$ d.[3]

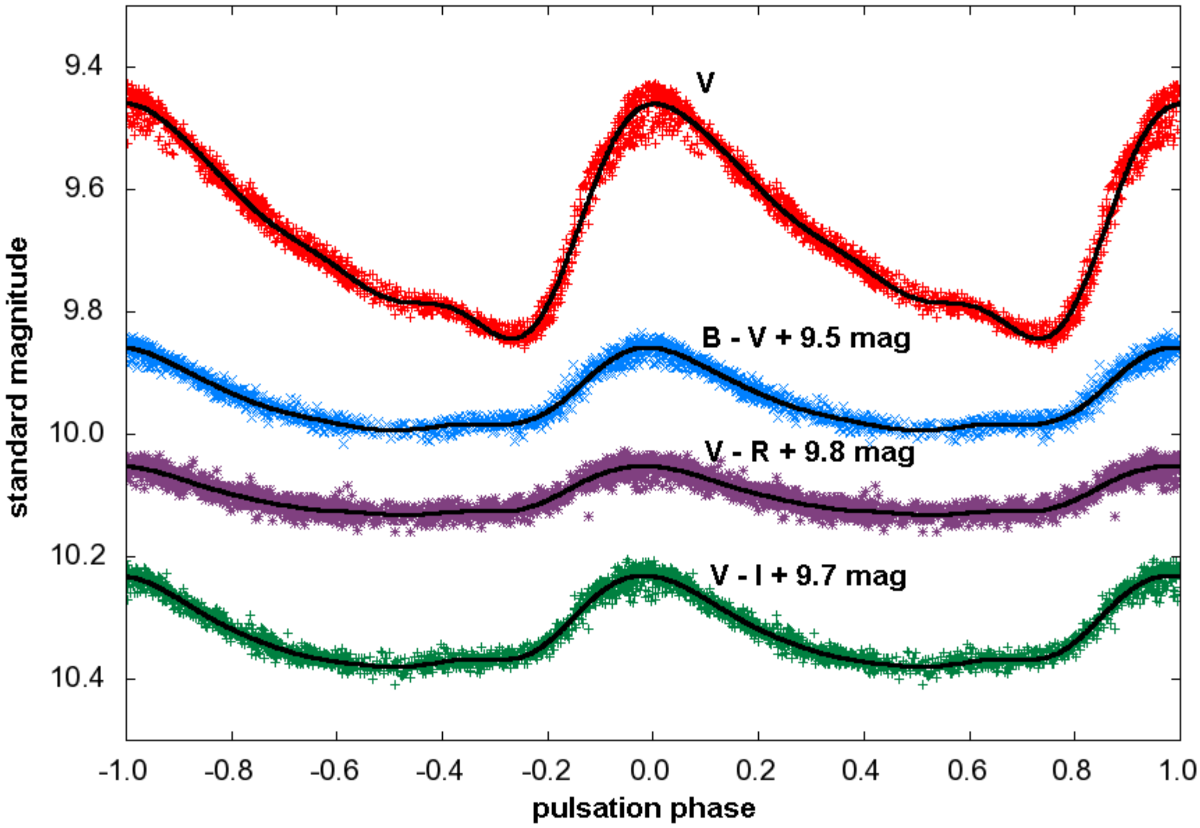

Figure 1. Calibrated data of CN Cam folded according to equation 1. The solid lines are the light curve fit with the sum of sines.

Although the coverage of the light curves was not ideal, we fitted V, $B - V$, $V - R$ and $V - I$ data with the sum of sines and we got the approximations of the mean light curves (Figure 1). The degree of the fit was chosen based on visual inspection. Analysing the mean light curves allowed us to determine Fourier coefficients based on the sine-term decomposition of the V light curve, and it also allowed us to estimate mean color indices, mean magnitudes (zero points), mean amplitudes and mean rise-time (duration from minimum to maximum in phase) during the Blazhko cycle (see Table 2). The times and the values of the extrema for rise-time and amplitude estimation were determined using LESVEPHOTOMETRY as mentioned above.

We could estimate metallicity of CN Cam using Fourier coefficients and pulsation period. Formula (3) from Jurcsik & Kovács (1996) gives $[{\rm Fe/H}]_{\rm JK} = -0.90$ dex. Transforming this value to the more common Zinn & West (1984) scale using the $[{\rm Fe/H}]_{\rm ZW} =$

[3] All values of frequencies and periods in this paragraph are based on V data analysis

$1.05[\mathrm{Fe/H}]_{\mathrm{JK}}-0.20$ relation, adopted from Sandage (2004), we obtained $[\mathrm{Fe/H}]_{\mathrm{ZW}} = -1.15$ dex, which agrees well with the spectroscopic value $[\mathrm{Fe/H}] = -1.2$ dex given in K07.

Following the analysis in K07, our parameters gave: $[\mathrm{Fe/H}] = -1.15$ with Sandage's equation (3),[4] $[\mathrm{Fe/H}] = -1.05$ with Sandage's relation (6) and $[\mathrm{Fe/H}] = -1.00$ with Sandage's equation (7) (with rise-time 0.272). If we fix our metallicity at $[\mathrm{Fe/H}] = -1.15$ dex and consider the calibration

$$M_V = 0.214[\mathrm{Fe/H}] + 0.86 \qquad (2)$$

of Clementini et al. (2003) we obtain $M_V = 0.61$ mag. The distance of CN Cam is therefore 608 pc.[5]

Table 2. Characteristics of the light curves and sine-term Fourier coefficients based on the V light curve fit. N is the degree of the fit, A_0 denotes the mean magnitude. Phases ϕ_{ij} are in radians, Fourier combinations R_{ij} in mag.

	N	A_0 [mag]	max [mag]	amplitude [mag]	rise-time
B	4	10.1168(7)	9.817(3)	0.510(4)	0.268(4)
V	4	9.6751(4)	9.460(2)	0.384(3)	0.272(4)
R_c	4	9.3703(4)	9.207(2)	0.313(3)	0.272(4)
I_c	4	9.0460(3)	8.925(2)	0.253(3)	0.282(4)
$B-V$	4	0.4456(4)	0.358(2)	0.130(4)	
$V-R$	5	0.3022(3)	0.252(4)	0.079(4)	
$V-I$	5	0.6262(9)	0.531(3)	0.149(4)	
ϕ_{21}	ϕ_{31}	ϕ_{41}	R_{21}	R_{31}	R_{41}
2.578(13)	5.567(28)	2.984(74)	0.365(5)	0.155(4)	0.054(4)

Amplitudes and zero points of our mean light curves differ from the values given by CC96 and K07. Our range in $(B-V)$ (0.358(2)-0.488(3)) is significantly higher than $0.26-0.38$ mag (CC96) and $0.325-0.454$ mag (K07). According to our $(B-V)$ range CN Cam varies between spectral types F2 to F6. Our amplitude in $B = 0.510(4)$ mag is also larger than 0.474(4) mag (CC96) and 0.49 mag (K07). Our metallicity estimation is slightly lower than K07 derived, but close to the value based on spectroscopy.

All the discrepancies are probably caused by changing characteristics during the Blazhko cycle, which were not caught in CC96 and K07 (visual estimates of the amplitude of the modulation in V is about 0.09 mag and about 0.11 in B). The slightly different magnitude of the comparison star that we used can also play a minor role. Our mean light curves could also differ from the 'true' mean light curves due to non-uniform coverage of our light curves ('true' mean amplitudes of BVR_cI_c are probably slightly lower than ours). For more reliable analysis more extended observations will be needed.

In the future we plan to focus on the observations of other interesting or poorly observed stars with stable and also with modulated light curves. We will also try to complete missing parts of the light curves of already observed stars. Any new observer interested in RR Lyraes is warmly welcome to join CRRLSOP.

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[4] to use Sandage's (2004) equation (3), ϕ_{31} from the Table 2 has to be decreased by the parameter π

[5] taking into account the extinction $\mathrm{E}(B-V) = 0.047$ from Schlegel et al. (1998)

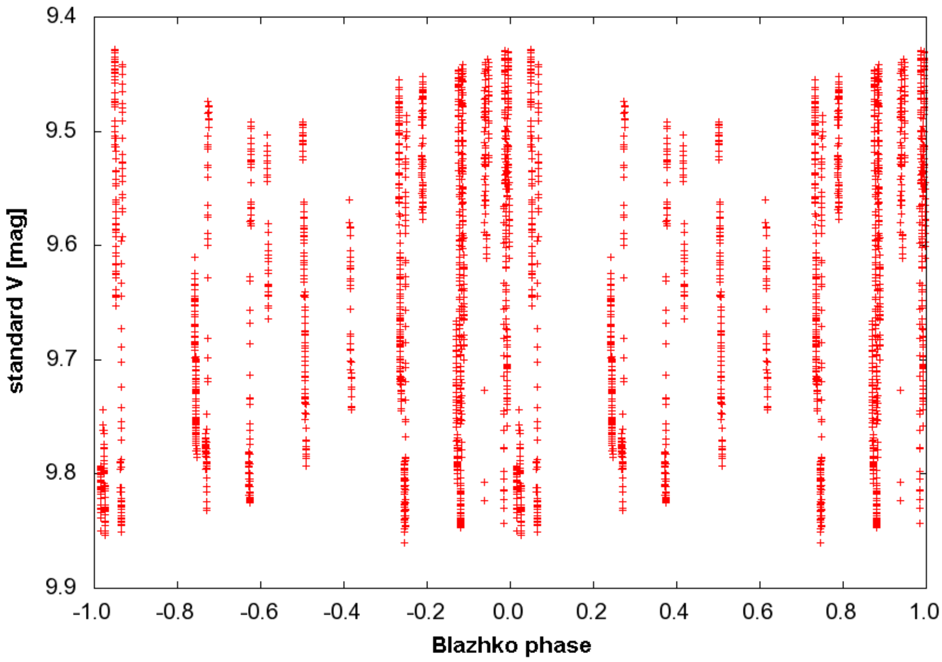

Figure 2. Standard V data phased with the period 47.25 d according to the epoch given in equation 1.

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