Photometrical observations some RR Lyr type-stars with Blazhko effect.

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1. V365 Her

The variability of the star was found by C. Hoffmeister in 1936. The star thoroughly was investigated by V. P. Tsessevich, which determined the primary elements of period: Max. hel. J.D. = 2436047.522 + 0.6130535 E, and discovered the sophisticated shape of light variation curves, known as Bllazhko effect (40.64 day) (Tsessevich, 1961, 1966). He mentioned, that the curve of maximum height shows considerable dispersion, and it seems, that the most part of time we observe the weakened maxima and only in some time intervals (short-term) we observe the maxima in the considerable heights. It indicates in modulation of a light curves by additional frequencies, and the star represents the scientific interest for observations. Visual observations in 20 century were carried out by Hoffmeister and Tsessevich. Now V365 Her is known as RR Lyr-star type (RRab) with amplitude $12.^m7 - 14.^m0$ (P), has period $0.^d613138$, Kholopov et al. (1985).

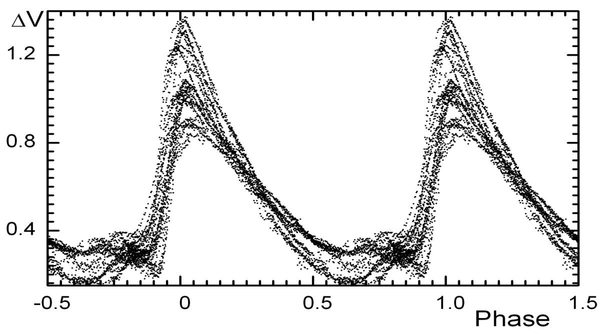

Figure 1: The light curves V365 Her with phase of basic period. The strong Blazhko modulation of amplitude reach about 0.5 mag and phase modulations up to 0.05.

The frequency analyses were performed using a package Period04, (Lenz and Breger, 2004). The pulsation period was determined with this package as the highest peak on the Fourier amplitude spectra. The all light curves V365 Her with pulsating period are shown on fig. 1. These phase curves were computed from elements:

Max HJD=2454978.403+ 0.613182 * E.

The maximum of the light curves amplitude variation is 1.3 mag, minimum 0.8 mag, and strong Blazhko modulation of amplitude reach about 0.5 mag and phase modulations up to 0.05. After prewhitening of basic frequency the harmonics of basic frequency kf0 and triplet of frequencies $kf_0 \pm f_m$, responsible for modulation of light curves was found. The Fourier amplitude and phases of the pulsation component identified in the spectra of the light curves of V365 Her are presented in Table 1. The basic frequency denoted as f_0, the modulation frequency of Blazhko effect denote as f_m. From obtained data the mean period of Blazhko effect amount $14^d.6$.

Table 1: Identified Fourier amplitude and phases of the pulsation and modulation frequencies in light curves of V365 Her.

Identif.	Frequency	Amplitude	Phase	S/N
f0	1.630835	0.346	0.15	6.6
2f0	3.26168	0.127	0.86	26.7
3f0	4.89255	0.086	0.89	20.2
4f0	6.52330	0.061	0.22	13.1
5f0	8.15355	0.052	0.15	11.7
6f0	9.78498	0.021	0.43	6.1
7f0	11.41402	0.021	0.68	4.6
f0+fm	1.65552	0.085	0.33	17.2
f0- fm	1.60613	0.054	0.54	11.7
2f0-fm	3.22425	0.034	0.74	6.6
3f0+fm	4.91979	0.034	0.83	7.1
3f0-fm	4.85806	0.026	0.85	7.0
4f0+fm	6.5530	0.034	0.26	7.6
5f0+fm	8.1788	0.038	0.80	6.7
6f0-fm	9.74763	0.024	0.47	6.1

2. DM Cyg

The variability of the star was found by L. P. Tserasskaya in 1928. The star thoroughly was investigated by D. Ya. Martynov, which determined the primary elements of period. V. P. Tsessevich referred this star to type of the stars with suddenly variations of period. Visual observations in 20 century were carried out by Toronjadze, Esh, Martynov, Dombrovskiy, Selivanov, Gur'ev, Satyvaldyev, Born, Sofronevich, Alaniya, Lange, Lysova, Firmanuk, Braude at all, Tsessevich(1966). The period of Blazhko effect (26^d), found by Lysona & Firmanyuk (1980) was not comfirmed (Sodor & Jurcsik 2005).

Now DM Cyg is known as RR Lyr-star type (RRab) with amplitude $10.^m93 - 11.^m99$ (V), has spectr A9-F6 and period $0.^d41986$, Kholopov et al. (1985).

For all observations of DM Cyg were determined the magnitudes comparatively of comparison star. The phase curves were computed from elements:

Max HJD=2442582.406 + 0.4198600 * E, Samus et al. (1985).

The light curve shows small amplitude modulations about 0.07 mag and phase modulations up to 0.01. The V light curves DM Cyg and the utmost case of amplitude modulation are shown on fig. 2. These small modulation determine the small Blazhko effect of the star.

The frequency analyses were performed using a package of computer programs with single-frequency and multiple-frequency techniques by using utilize Fourier as well as multiple-least-squares algorithms (program Period04, Lenz and Breger, 2004).

The spectrum has been prewhitened for the pulsation component up to f12. Do not all datas were used for frequency analyses. The differences between V instrumental system allow to take only a part data 2008 year and 2009 entirely. The Fourier amplitude and phases of the pulsation component identified in the spectra of the light curves of DM Cyg are presented in Table 2. The basic frequency denoted as f_0, the modulation frequency of Blazhko effect denote as f_B. The errors of the amplitudes are 0.00024, the errors of frequencies and phases are given in table. With increasing order of frequencies the amplitudes of the pulsation are decrease. We find triplet of frequencies $f_0 \pm f_B$, but, perhaps, there are more frequencies in the pulsation spectra of DM Cyg. The amplitude of the component f_0+f_B is larger then the amplitudes f_0-f_B component. This fact have an influence on delay light curve and phase: the maximum of the amplitude modulation precedes the phase of the time delay of the maxima.

From obtained data the frequency of Blazhko effect amount 0.0947 c/d and period $10^d.56$. These values are agree with results, published Jurcsik et al.(2009).

DM Cyg, variable star of RR Lyr type, has pulsations in fundamental mode and small Blazhko effect. The difference of the amplitudes between min and max is about 0.07 mag, Blazhko period about $10^d.56$. The frequency Fourier analyse of light curves shows the components $f_0 \pm f_B$ of spectra up to 9 order.

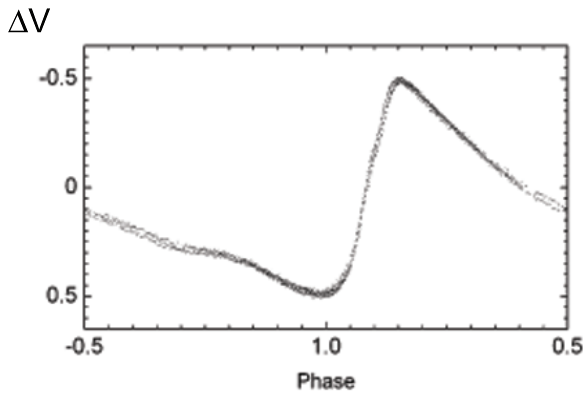

Figure 2: The two utmost case of amplitude modulation in the light curves DM Cyg.

Table 2: Identified Fourier amplitude and phases of the pulsation and modulation frequencies in light curves of DM Cyg.

	Identif.	Frequency	Sigma Fr.	Amplitude
f1	f_0	2.381670	0.000079	0.335680
f2	$2f_0$	4.763475	0.000014	0.181723
f3	$3f_0$	7.145023	0.000023	0.1118295
f4	$4f_0$	9.526944	0.000044	0.0598717
f5	$5f_0$	11.90858	0.000072	0.0366815
f6	$6f_0$	14.29043	0.000105	0.0251703
f7	$7f_0$	16.67200	0.000188	0.0141136
f8	f_0+f_B	2.475495	0.000221	0.0120192
f9	$3f_0+f_B$	7.239372	0.000317	0.0083993
f10	$8f_0$	19.05422	0.000331	0.00803232
f11	$5f_0+f_B$	12.00350	0.000503	0.00529077
f12	$7f_0+f_B$	16.76747	0.000566	0.00470369
f13	f_0-f_B	2.285704	0.000394	0.00674569
f14	$2f_0+f_B$	4.860136	0.000019	0.135926
f15	$9f_0$	21.43453	0.000652	0.00408199
f16	$4f_0+f_B$	9.617718	0.000641	0.00414875
f17	$12f_0$	28.57882	0.001018	0.00261339
f18	$9f_0+f_B$	21.53040	0.001006	0.00264637

AE Leo

AE Leo (AN 1935.0206 , GSC 1437.00734, NSVS 10338360,), ($\alpha_{J2000.0}$ = $11^h26^m12.2^s$; $\delta_{J2000.0}$ = $+17°39^{'}39.7^{''}$) The variability of the star was found by Morgenroth in 1935, as a variable star in list of the 31 new variables (Morgenroth, 1935). The finding chart for this star was published by N.E.Kurochkin (1949). The star thoroughly was investigated by L.Meinunger, which determined the primary period and 32 times of light maxima, using the old photographic plates from 1913 to 1961 years (Meinunger, 1961). The visual observations in 20 century were carried out by B.N.Firmanyuk and V.G.Derevyagin in 1987, Huebscher et al., in 1989 (Paschke, 2008). Now AE Leo is known as RR Lyr-type RRab star (GCVS) with amplitude $11.^m6 - 12.^m.8$ (P) and period $0.^d626723$ (Samus et al., 2011).

The photometric CCD observations of AE Leo in Astronomical station near Odessa in observation season 2013,2015,2017 years have been carried out. The standard reductions of the CCD frames were carried out using the MUNIPACK (Motl, 2009-17) software. The procedures for the aperture photometry is composed of the dark-level and flat-field corrections and determination of the instrumental magnitude and precision. To convert the differential magnitudes to the corresponding magnitudes of the variable, were used the comparison star V magnitude from APASS-catalog (2010). The errors on individual data points vary between 0.005 mag to 0.02 mag.

For all our observations of AE Leo were determined the magnitudes comparatively of comparison star. The frequency analyses were performed using a package of computer programs with single-frequency and multiple-frequency techniques by using utilize Fourier as well as multiple-least-squares algorithms (program Period04, Lenz and Breger, 2004). The pulsation period was determined with this package as the highest peak on the Fourier amplitude spectra. The all light curves AE Leo with pulsating period are shown on fig.3. These phase curves were computed from elements:

Max HJD=2419839.549 + 0.6267074 * E.

The value in maxima of the light curves vary from 11.77 mag to 11.90 mag, moderate Blazhko modulation of amplitude reach about 0.13 mag and no phase-shift modulations. The maxima of the pulsation cycles were determined for our analysis.

After prewhitening of basic frequency the harmonics of basic frequency kf0 and f_m frequency responsible for modulation of light curves was found. The Fourier amplitude and phases of the pulsation component identified in the spectra of the light curves of AE Leo are presented in Table 3. The basic frequency denoted as f_0,

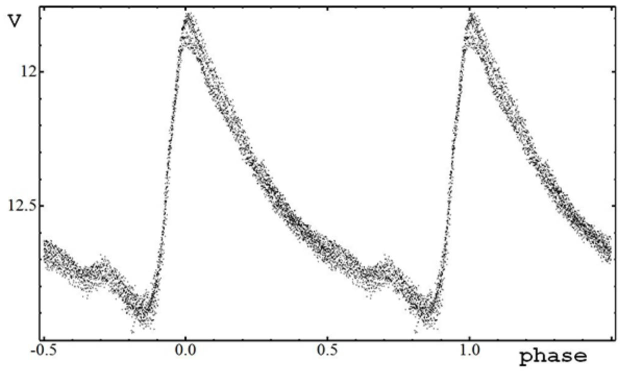

Figure 3: The phase curves of AE Leo from our observations. The moderate Blazhko modulation of amplitude reach about 0.13 mag

the modulation frequency of Blazhko effect denote as f_m. We find seven frequencies, but, perhaps, there are more frequencies in the pulsation spectra of AE Leo. From obtained data (Fourier analysis and the maxima height change) the preliminary value of Blazhko effect period is amount 12^d.

Table 3: Identified Fourier amplitude and phases of the pulsation and modulation frequencies in light curves of AE Leo.

Identif.	Frequency	Amplitude	Phase	S/N
f0	1.595519	0.370	0.86	5.3
2f0	3.191036	0.190	0.47	57.6
3f0	4.786535	0.117	0.95	40.0
4f0	6.380688	0.078	0.72	31.2
5f0	7.977561	0.044	0.15	18.3
6f0	9.573121	0.024	0.39	10.4
7f0	11.16721	0.019	0.40	8.3
f0-fm	1.51316	0.015	0.11	4.6

Y Vul

Y Vul (AN 1907.0004, Gaia DR1 - 286.0678990585, USNO-A2.0 1125 - 11247385), ($\alpha_{J2000.0} = 19^h04^m16.3^s$; $\delta_{J2000.0} = +24°47'19.1''$) is known as the variable star for more than hundred years, but this RRab variable has been poorly investigated. The variability of the star was explored by Biesbroeck and Casteels, (1960), and they have defined that the star belongs to RR Lyr variables. However, in spite of their detailed observations, the authors haven't deduced the light curve elements. Using observation data, reported by van Biesbroeck and Casteels, (1960) derived a period and epoch of Y Vul as follows:

$$MaxJD = 2419221.531 + 0^d.44941 \times E. \quad (1)$$

He pointed out the difference in height of the light curves maxima and suspected the presence of the Blazhko effect in Y Vul. Using photographic observations in the range JD 2433034-41492, Kazarovets and Shugarov, (1973) determined elements of the light-curve variation more accurately:

$$MaxJD = 2438939.413 + 0^d.44945164 \times E. \quad (2)$$

Their estimated range of the light variation was $14^m.2$ - $16^m.0$ (pg). The data reported in their study for Y Vul were included to the General Catalogue of Variable Stars (GCVS) and AAVSO Variable Star Index (VSX database, https://www.aavso.org/vsx/index.php).

The photometric CCD observations of Y Vul were obtained at the Astronomical station near Odesa during the observation seasons in 2011-12, 2014-17. The datasets consists of 4290 V-band data points and 1665 Rc-band points obtaind from over 53 nights of observations.

The modulation occurs at the maximum brightness and phase shift too. The brightness at maxima of the light curves in Rc-band vary from $14^m.265$ to $14^m.411$, the moderate Blazhko modulation of the amplitude reaches about 0.146; in V-band vary from $14^m.316$ to $14^m.478$, and the modulation reaches $0^m.162$. The phase shift modulation in both bands varies within about 0.041 of the pulsation phase.

To analyse the modulation properties of the light curves for this star, we have used a common technique a Fourier decomposition. The frequency analysis was performed using a package of computer programs with sine-wave fitting by using utilize Fourier algorithms (program Period04). The fundamental pulsation period was determined with the help of using the above-mentioned techniques as the highest peak on the Fourier amplitude spectrum. The observed harmonics and triplet were defined by pre-whitening data and Fourier analysis of the residuals. The Fourier spectra of the Y Vul light curves are described by the triplet frequencies $kf_0 \pm f_m$ and the modulation frequency f_m. In the frequency spectrum the pulsation harmonic components are detected up to the 7^{th} order; the modulation side lobe frequencies are detected up to 9^{th} order. Thirty pulsation maxima from the observed light curves have been measured. The Blazhko frequency also was determined as the difference of frequencies $f_m = kf_0 - kf_0 \pm f_m$. The average value of the Blazhko period equals 0.01689 ± 0.0004 cd^{-1}, whith corresponds to the period of 59.20 ± 0.14 day.

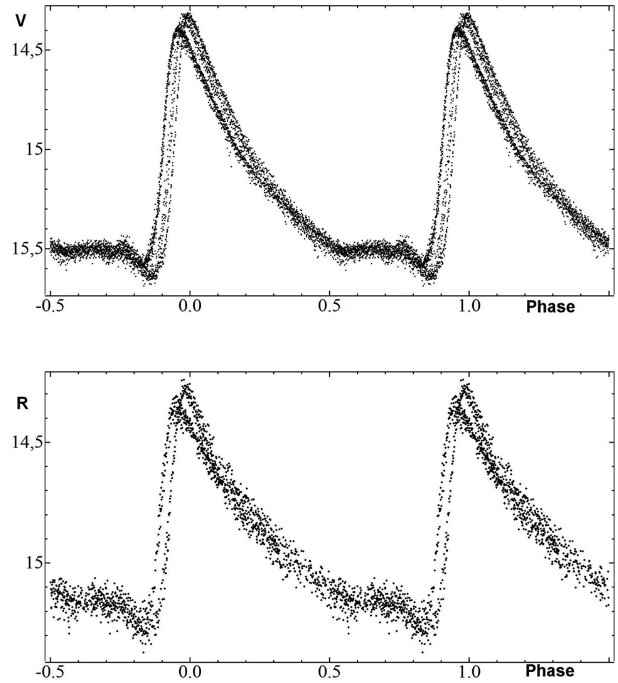

Figure 4: The phase curves of Y Vul in V and Rc filters.

Table 4: Identify frequencies, amplitudes and modulation frequencies $f_m = kf_0 - kf_0 \pm f_m$ of the light curve solutions of Y Vul.

Identification	**f (cd^{-1})**	**amplitude, mag**	**snr**
f_0	2.224936(2)	0.311(1)	94.2
$2f_0$	4.449874(3)	0.187(2)	35.2
$3f_0$	6.674817(3)	0.160(1)	31.4
$4f_0$	8.899735(3)	0.100(2)	22.1
$5f_0$	11.12464(1)	0.050(4)	13.5
$7f_0$	15.5717(6)	0.029(8)	9.2
f_0+f_m	2.24188(3)	0.031(9)	7.1
f_0-f_m	2.20803(6)	0.027(8)	6.7
$2f_0-f_m$	4.433004(9)	0.051(2)	5.6
$3f_0+f_m$	6.691688(7)	0.046(2)	9.3
$4f_0+f_m$	8.91661(1)	0.040(2)	9.5
$6f_0-f_m$	13.33284(5)	0.038(9)	11.4
$7f_0+f_m$	15.59158(2)	0.018(3)	4.5
$8f_0-f_m$	17.78265(1)	0.017(2)	4.0
$9f_0+f_m$	20.0076(1)	0.09(1)	7.2

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