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MV Lyrae: Photometric study at high state

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Abstract. Photoelectric observations of novalike MV Lyr in a standard UBV system were carried out at Rozhen and Belogradchik observatories in 1992 and 1993. During all the nights of observations the star was in high state ($V \sim 12.5$ mag). The observing runs performed in U and B bands show strong flickering activity and a typical shape of the red noise power spectrum. The periodogram analysis of time series shows quasi-periodic oscillations with a period of about 50 min. The excitation of trapped oscillations at the outer edge of the accretion disc, has been proposed as a possible mechanism for generation of MV Lyr quasi-periodic oscillations. The properties of the flickering in MV Lyr light curves were determined.

Key words: accretion, accretion disks — stars: MV Lyr — stars: novae, cataclysmic variables — X-ray: stars

1. Introduction

The novalike MV Lyr has been classified during the last years as a VY Scl type cataclysmic variable (Ritter 1990). The long-term photometric characteristics of the star were established photographically by Weber (1961); Romano & Rosino (1980); Andronov & Shugarov (1982); Wenzel & Fuhrmann (1983); Andronov et al. (1988); Kraicheva & Genkov (1992); Rosino et al. (1993). These investigations showed that MV Lyr brightness varies irregularly between high ($B \simeq 12.5$ mag) and low ($B \simeq 18$ mag) states. Photoelectric studies of MV Lyr in high state carried out by Borisov (1992) and Skillman et al. (1995) pointed at two modulations presented simultaneously, one with a mean period of $0\overset{\mathrm{d}}{.}1379$ and another with a mean period of $3\overset{\mathrm{d}}{.}8$. The existence of quasi-periodic oscillations (QPOs) with a period near 47 min has also been assumed. Walker (1966) suspected that MV Lyr is a single-lined spectroscopic binary. Schneider et al. (1981) found its orbital period to be $0\overset{\mathrm{d}}{.}1336 \pm 0.0017$. At maximum the light curves displayed large amplitude flickering with a peak-to-peak amplitude reaching 0.3−0.4 mag (Walker 1954; Robinson et al. 1981). MV Lyr is also soft (Mason et al. 1979) and hard (Cordova et al. 1981) X-ray source.

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Table 1. Observational series of MV Lyr

Date	Start time [UT]	Length [hours]	Filter
1992 Jul. 05	$22^{h}20^{m}$	$2^{h}15^{m}$	B
1992 Jul. 06	$22^{h}15^{m}$	$2^{h}32^{m}$	U
1993 Jul. 17	$20^{h}55^{m}$	$3^{h}07^{m}$	U
1993 Jul. 17	$20^{h}34^{m}$	$3^{h}20^{m}$	B
1993 Jul. 18	$22^{h}13^{m}$	$3^{h}13^{m}$	U
1993 Jul. 19	$21^{h}06^{m}$	$3^{h}00^{m}$	U
1993 Jul. 19	$21^{h}07^{m}$	$1^{h}40^{m}$	B
1993 Jul. 20	$22^{h}30^{m}$	$1^{h}44^{m}$	B

In this paper we present our photoelectric observations of MV Lyr carried out during 1992−1993. The data were tested for periodic modulations and the flickering properties were investigated. In Sect. 5 a possible mechanism for the generation of the obseved "50 min" QPOs is discussed.

2. Observations and results

The data consist of 8 photoelectric series in the U and B photometric bands with a duration from 1.6 to 3.3 hours. Apart from these series, there are 35 additional measurements in the standard UBV system obtained from July 1992 to October 1993. The integration time for all observations was 10 s and star "C" (see Walker 1954) served as a comparison star. The photoelectric data are summarized in Tables 1 and 2. All observations were carried out with the one-channel photometers attached to the 60-cm Carl Zeiss telescopes of the Rozhen and Belogradchik Observatories of the BAS. The observational data were processed with the reduction software described by Kirov et al. (1991).

Table 2. *UBV* observations of MV Lyr

Date	JD 2440000+	V	$B-V$	$U-B$
1992 Jul. 04	8808.435	12.569	−0.200	−1.025
	8808.449	12.673	−0.148	−0.896
	8808.498	12.649	−0.144	−0.977
1992 Jul. 05	8809.386	12.640	−0.088	−0.903
	8809.394	12.627	−0.123	−0.956
	8809.402	12.626	−0.113	−0.982
1992 Jul. 06	8810.382	12.602	−0.129	−1.002
	8810.390	12.664	−0.164	−0.898
	8810.398	12.706	−0.134	−0.979
1993 Jul. 18	9186.512	12.575	−0.150	−0.938
	9186.521	12.433	−0.114	−1.062
	9186.531	12.551	−0.151	−1.067
	9186.540	12.593	−0.176	−1.026
	9187.395	12.386	−0.169	−0.944
	9187.400	12.505	−0.231	−1.037
	9187.410	12.471	−0.164	−0.975
	9187.414	12.477	−0.132	−0.946
1993 Jul. 20	9188.524	12.491	−0.205	−0.990
	9188.528	12.420	−0.169	−1.041
1993 Aug. 23	9223.343	12.607	−0.165	−1.042
	9223.351	12.462	−0.188	−1.084
	9223.359	12.565	−0.169	−1.080
	9223.369	12.553	−0.162	−1.059
1993 Sep. 12	9243.459	12.439	−0.131	−0.950
	9243.468	12.320	−0.071	−0.993
	9243.476	12.561	−0.120	−1.002
	9243.480	12.527	−0.047	−0.929
	9243.490	12.561	−0.164	−1.058
	9243.498	12.354	−0.104	−0.995
1993 Sep. 13	9244.478	12.629	−0.141	−1.077
	9244.487	12.553	−0.156	−1.010
	9244.496	12.629	−0.199	−1.089
1993 Oct. 12	9273.371	12.562	−0.175	−0.929
	9273.381	12.505	−0.151	−0.972
	9273.391	12.485	−0.147	−0.989

The UBV data are shown in Table 2 and Fig. 1. They cover the ascending branch top end of the long-term light curve after the star had left its 1979 – 1989 low state (Wenzel & Fuhrmann 1989; Kraicheva & Genkov 1992; Rosino et al. 1993). During all the nights of observations the star was in active state and reached its maximal brightness gradually: for a year the mean brightness increased by about 0.15 mag in the V and B bands and 0.20 mag in the U band. The behaviour of another member of the VY Scl novalikes, TT Ari, was the same after returning to high state (Kraicheva et al. 1987). The MV Lyr colors varied between −0.05 and −0.23 for $B-V$ and between −0.90 and −1.09 for $U-B$. According to Robinson et al. (1981) and Rosino et al. (1993) at low and intermediate state the colors of MV Lyr are usually somewhat bluer with $B-V \simeq -0.35$ and $U-B \simeq -1.25$. Our observations showed a linear correlation between U, B and V magnitudes (Fig. 1). The slopes of the dependencies $U(B)$ and $V(B)$ are 1.16 ± 0.10 and 0.89 ± 0.07, respectively, and indicate that the largest change is in U and the least is in V band. The data obtained in 1992 as well as those obtained in 1993 follow the same tracks.

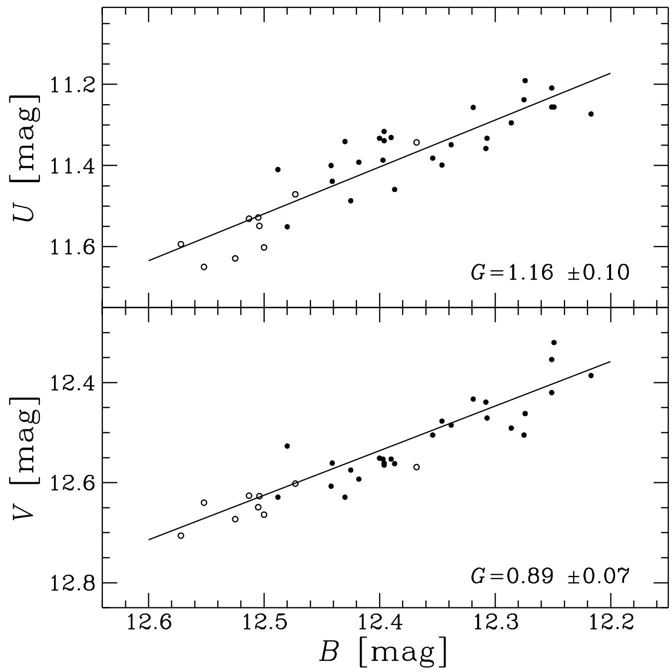

Fig. 1. $U(B)$ and $V(B)$ diagrams for the UBV observations in 1992 (open circles) and 1993 (points)

3. Periodicity search

The method of Scargle (1982) was applied to search for periodic variations in MV Lyr light curves. Because of gaps in the runs, the Nyquist frequency is not defined and the power spectra (PS) were calculated up to frequencies less than $f_N = 1/2\Delta t$, where Δt is the integration time.

The power spectra of the MV Lyr light curves show a typical for a red noise shape: power law $P(f) \sim f^{-\gamma}$ in the high frequencies. This considerably modifies the power distribution and the use of "false alarm" probability gives an unreal high statistical significance of the detected peaks (Tremko et al. 1996). According to van der Klis (1989) the variance of the red noise power spectrum is proportional to the local mean power $\sigma_P \sim \langle P \rangle$. Then a correct procedure would be to divide the PS by some mean red noise shape in order to bring the spectrum back to constant variance and then to evaluate the significance of the peaks. In the case of MV Lyr the mean red noise shape would be found through fitting the PS to function $\alpha/(1+(2\pi f\tau)^\gamma)$ (α, τ and γ are the parameters which we search for). Unfortunately, because of the large power scatter and the three unknown parameters the fitting procedure fails in the low frequencies and in practice we cannot use it.

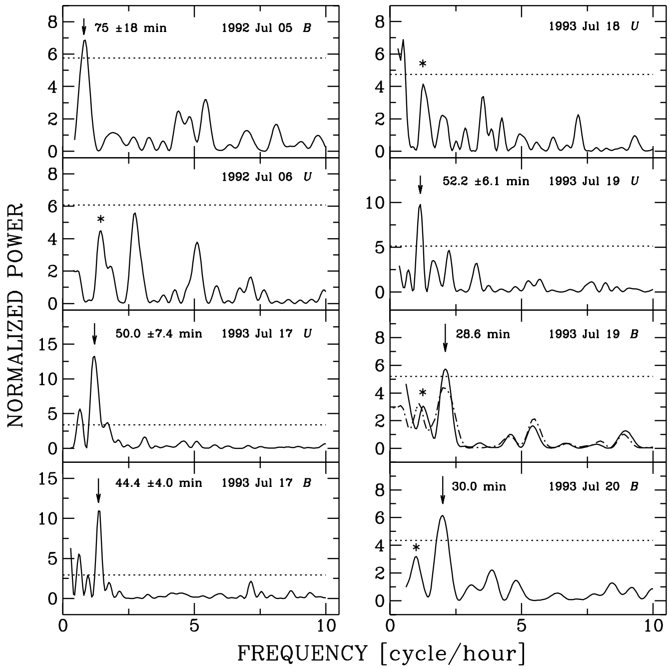

Fig. 2. Power spectra of MV Lyr light curves (normalized to the mean power). Dashed lines mark 99% significance levels. Dash-dotted curve is the PS of a part of the U run on Jul. 19, 1993 as discussed in the text. $*$ marks the peaks of "50 min" QPOs below 99% significance level

To estimate the statistical significance of the peaks in the PS we used a rougher procedure. The PS of MV Lyr light curves are nearly constant in the frequencies approximately below 10 $[c/h]$ (Fig. 5). This allows to apply "false alarm" probability without normalization of the power spectra in the frequency interval from 0 to 10 $[c/h]$. The power distribution in every PS was approximated with exponential function $\exp(-P/P_0)$ and 99% significance levels were calculated by equation:

$$z_0 = -P_0 \ln(1 - 0.99^{1/K}). \tag{1}$$

$K \simeq 10/\Delta f$ is the number of the independent frequencies in the interval 0−10 $[c/h]$, where $\Delta f = 1/T$. T is the total length of the run in hours. To determine the power distribution better, the spectra were oversampled by a factor of 3. The results are shown in Fig. 2. The uncertainties included in the figure are equal to HWHM of the peaks.

In four of the runs statistical significant periodicities of about 50 min were detected. In all other runs peaks corresponding to "50 min" QPOs are seen also but they are below the 99% significance level. There are two peaks corresponding to periods about 30 min which are detected as significant also. Our opinion is that they are not due to real periodicities. The reasons for their presence can be the small length of these runs and some strong flickering peaks appearing in the minimum of "50 min" QPOs (Fig. 3). The B runs on 19 and 20 Jul., 1993 contain only two maxima of "50 min" QPOs and the flickering peaks at the minimum cause the peak in the PS corresponding to a period shorter by a factor of 2. We calculated the PS of this part of U run on Jul. 19, 1993 (with gaps introduced as in the B curve) which coincided with the B curve. From Fig. 2 it can be seen that the two PS are almost the same. Although the peaks of "50 min" QPOs in the PS of the runs on Jul. 19 and 20, 1993 are not significant, the data allow to be fitted with corresponding periods. An inspection of the results shows that the period determined from the light curves obtained simultaneously on 17 of July differ by 5.5 min, in spite of the coincidence between them. We supposed that the long gaps in the B curve are responsible for this difference mainly. The period determined from the U curve, after removing of the data corresponding to the gaps in the B curve, was 45 min. So, we decided that the value 50.0 min is more reliable and accept it as typical of QPOs during the night. It is necessary to note that the curves from July 17, 1993 show a peculiarity: every second minimum of QPOs is deeper.

To study $0\overset{\mathrm{d}}{.}1379$ modulations of MV Lyr brightness reported by Borisov (1992) we used composite light curves for 1993 U and B bands observations. The PS did not show significant peaks in the vicinity of the corresponding frequency. The revision of the individual light curves, including those from 1992, showed that modulations with a period of about 3 hours could be suspected in the light curve from July 18, 1993 only. From the best sinusoidal fit a period of 3.22 hours was obtained. The data from July 5, 1992 show a linear trend which may be a result of 3.3 hours modulations also.

The sinusoidal fits to the individual light curves obtained using the found periods and the amplitudes determined from these fits are shown in Fig. 3. The amplitudes of 3.3 hours modulations are 0.055 and 0.063 mag for July 5, 1992 and July 18, 1993 respectively. They are close to the mean cycle amplitude of 0.042 mag found by Borisov (1992). In his individual curves, however, the amplitudes of the signal vary from 0.018 to 0.077 mag. Skillman et al. (1995) regard their Aug./Jul. 1993 data as supportive of $0\overset{\mathrm{d}}{.}1379$ signal only and admitted it to be a transient one. Therefore it is possible that this signal is present with lower amplitudes in most of our curves but is obscured by large amplitude flickering and QPOs, or is not present at all.

Unfortunately, we do not have observations in at least four consecutive nights, both in U and B bands and could not confirm the four day modulations. But the three consecutive U band observations indicate an increase of the mean star's brightness with ~ 0.06 mag. B band observations covering descending branch of the wave, show a decrease of the brightness with ~ 0.05 mag.

4. Flickering properties

To study flickering we used both the power spectra and autocorrelation function (ACF). As it was mentioned above,

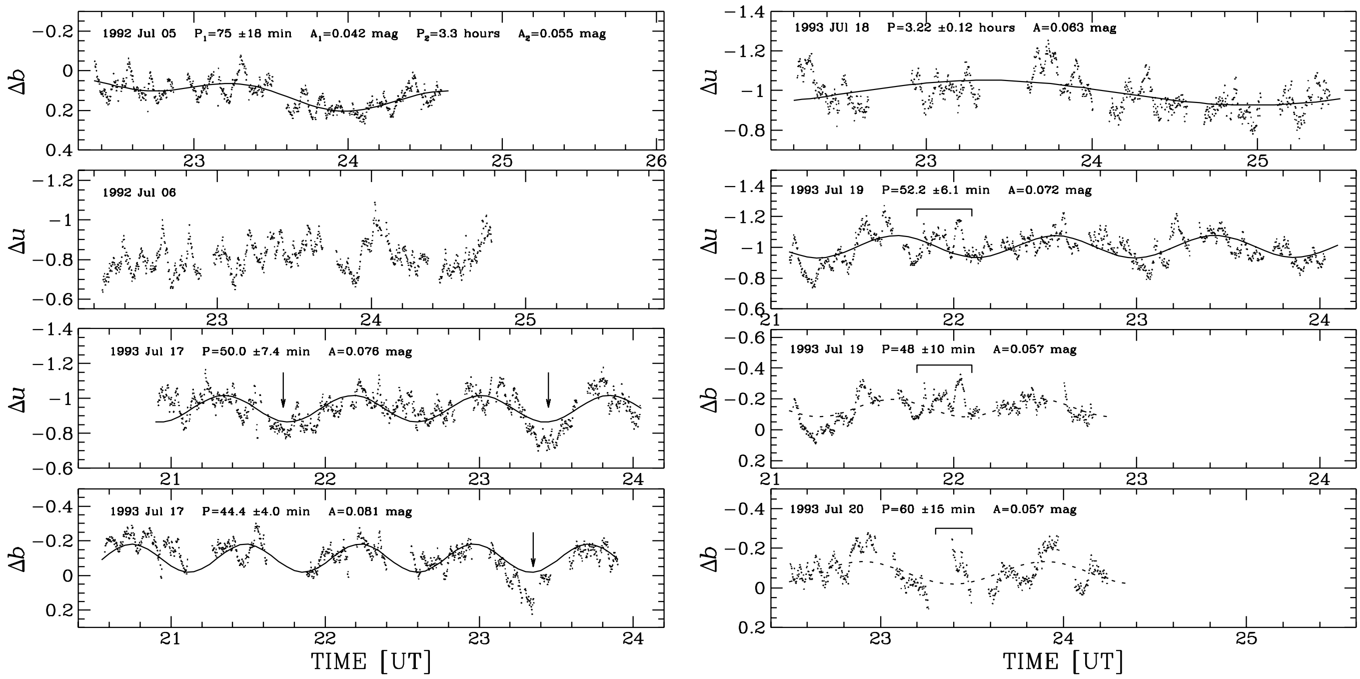

Fig. 3. The light curves of MV Lyr and the best fits to them. The arrows mark the deeper minima of the QPOs discussed in the text. "⊓" marks the strong flickering peaks appearing in some minima of the QPOs. The fits with dotted lines are performed with periods corresponding to peaks marked with ∗

PS of MV Lyr show a red noise. Although the presence of red noise in PS does not specify the underlying source variability, investigation of PS properties is useful from the point of view of their comparison with the ones predicted from the theoretical and numerical models. An important characteristic in this aspect is the power law index γ, as well as the common shape of the PS.

In order to determine γ we plotted PS in log-log scale and fitted their linear parts by least-squares linear fit. The interval in which the fits were performed varied from $5-10$ $[c/h]$ to $70-100$ $[c/h]$ (with one exception on Jul. 18, 1993 where the upper end of the linear part was 50 $[c/h]$). At frequencies higher than $70-100$ $[c/h]$ the spectra become flat because the white noise dominates over all other sources of variability. The values of γ are listed in Table 4 together with the errors determined from fitting program. The value of γ determined from the mean power spectrum and the mean γ from the individual values are also given in the table.

The data contain gaps with common length 10−30% of the run length. They cause power leakage effects and may reduce the power spectrum slope. To investigate the influence of these gaps on the accuracy of γ determination, we used the three series containing 10% gaps only (Jul. 06, 1992, Jul. 17 and 19, 1993). The gaps were filled using the method developed by Fahlman & Ulrych (1982). After that all original gaps were enlarged randomly, but keeping their common length 15, 20, 25 and 30% respectively. For every run and common length of the gaps, 100 different gaps distributions were introduced and the mean values of γ were compared with those determined from the filled and original runs. The mean values of γ showed slight tendency to decrease with the growth of the gaps length, but all values remained in the interval $\pm\sigma_\gamma \simeq 0.1$ determined from the 100 simulated gaps distributions. Because the PS are very noisy, the determination of γ also depends strongly on the interval in which the fit is performed. Small changes in this interval caused changes in the values of γ reaching $0.2-0.3$. So the errors listed in Table 4 should be regarded as a lower limit.

The time scale of the flickering is not an easily definable quantity. An objective way to define it is by autocorrelation function (ACF). The typical time scale of the flickering τ may be defined as the time shift at which the ACF $r(\tau)$ first accepts the value $r_0 = 1/e$. Thus determined correlation times are strongly biased from the presence of periodic brightness variations or some trends in the data. In order to flee the influence of these factors the following procedure was applied. The runs were divided into non-overlapping sections of $\sim$ 15 min each and the average points in these bins were interpolated by cubic spline. This roughly corresponds to output from a filter cutting modulations with periods approximately longer than 40 min. Finally the residuals between the original data and the smooth curve were analysed. Because of gaps in the observations the ACFs were calculated according to Edelson & Krolik (1988) and are shown in Fig. 4. The bin sizes were chosen to be equal to integration time.

Table 3. Flickering properties

Date	Filter	Amplitude [mag]	Standard deviation	τ [sec]	γ	$\frac{F_{\rm f,mean}}{F_{\rm c}}$	$\frac{F_{\rm f,max}}{F_{\rm c}}$
1992 Jul. 05	B	0.265	0.047	93 ± 5	2.01 ± 0.09	0.13	0.27
1992 Jul. 06	U	0.345	0.057	71 ± 5	2.15 ± 0.09	0.17	0.37
1993 Jul. 17	U	0.335	0.053	58 ± 5	1.63 ± 0.07	0.16	0.36
1993 Jul. 17	B	0.353	0.049	69 ± 6	1.75 ± 0.08	0.17	0.38
1993 Jul. 18	U	0.376	0.061	83 ± 6	1.83 ± 0.16	0.19	0.41
1993 Jul. 19	U	0.365	0.068	90 ± 6	1.84 ± 0.04	0.18	0.39
1993 Jul. 19	B	0.304	0.060	87 ± 9	2.03 ± 0.09	0.15	0.32
1993 Jul. 20	B	0.366	0.065	130 ± 15	1.70 ± 0.11	0.18	0.39
Mean				$85 \pm 22^*$	$1.87 \pm 0.18^*$		
Mean PS					1.89 ± 0.03		

The errors of the individual γ are determined by fitting program and they are formal ones. As was discussed in text the real errors reach to $\simeq 0.2 - 0.3$. * – standard deviations of the mean values.

Determined correlation times listed in Table 4 are of the order of 1.5 min. The errors are determined from shift times at which the functions $r(\tau) \pm \Delta r(\tau)$ first reach the value $r_0 = 1/e$, where $\Delta r(\tau)$ are the errors of the autocorrelation coefficients. In the table is also given the mean from the individual values. As Robinson & Nather (1971) and Panek (1980) note, these correlation times can be additionally biased by the presence of weakly correlated noise and the way of trend removal. When periodic components are detrended the real shape of the signal cannot be found exactly and this leads to so called residual noise. In the procedure described above this noise is caused by the influence of the flickering on the determination of the mean values. However in case of averaging over long enough bins the amplitudes of the residuals will be small compared with those of the flickering and the results will be weakly affected by the residual noise.

The determined values of γ vary in the interval from 1.60 to 2.15. There are several mechanisms which may produce PS with power law shape and γ in this interval (see Tremko et al. 1996). The low frequency flat part of PS allows us to suggest a model of the optical variability in terms of a "shot noise" process. According to this model the light curves are the result of overlapping, randomly distributed in time shots with some shape. In the classic "shot noise" model the shots are assumed as decaying exponents. Then PS shape is:

$$P(f) \propto \frac{1}{1 + (2\pi\tau f)^2} \quad (2)$$

where τ is e-folding constant of the shots. Autocorrelation function of a shot noise curve has a shape $r(t) \propto \exp(-t/\tau)$, where t is the shift time. In practice, because of the finite length of the observations and the overlapping of the shots, the ACF does not follow this shape but crosses the zero level at some lag and after that oscillates around it (see for example Andronov 1994). To verify the influence of this effect on the determination of τ, artificial shot noise series with time resolution 10 sec were simulated as a sum of randomly distributed in time one- and two-sided exponential shots. τ and the overlapping parameter $N = \tau\lambda$ (λ is the mean shot rate) were varied between 1–5 min and 1–5 respectively. The correlation times determined by ACFs were compared with the accepted ones. In all cases the relative scatter of the values σ_τ/τ was smaller than 0.25 and the mean value was close to the accepted one $|\tau_{\rm mean} - \tau|/\tau < 0.1$. Although the common shape of the ACF is strongly biased by the finite length of the data and the shots overlapping, for small lags the calculated ACFs are close to the theoretical ones and the mean value of τ

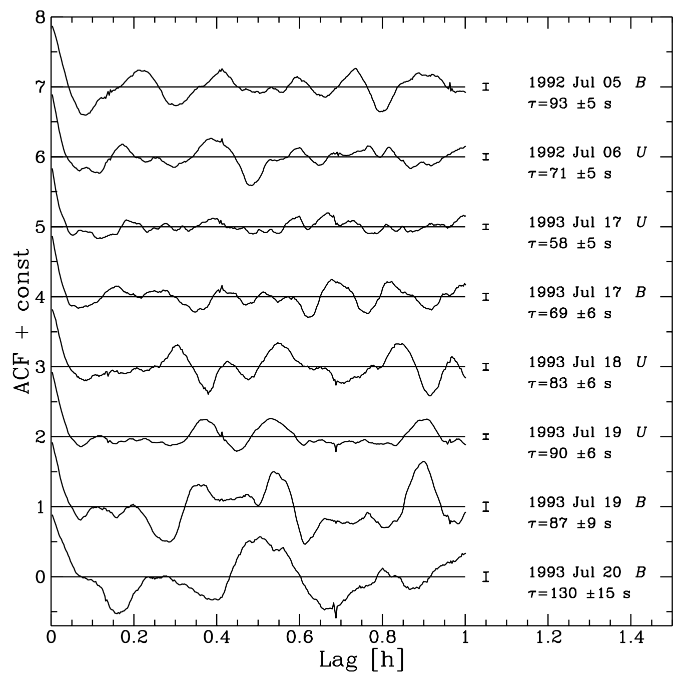

Fig. 4. Autocorrelation functions of MV Lyr light curves. Bars show the errors of the autocorrelation coefficients

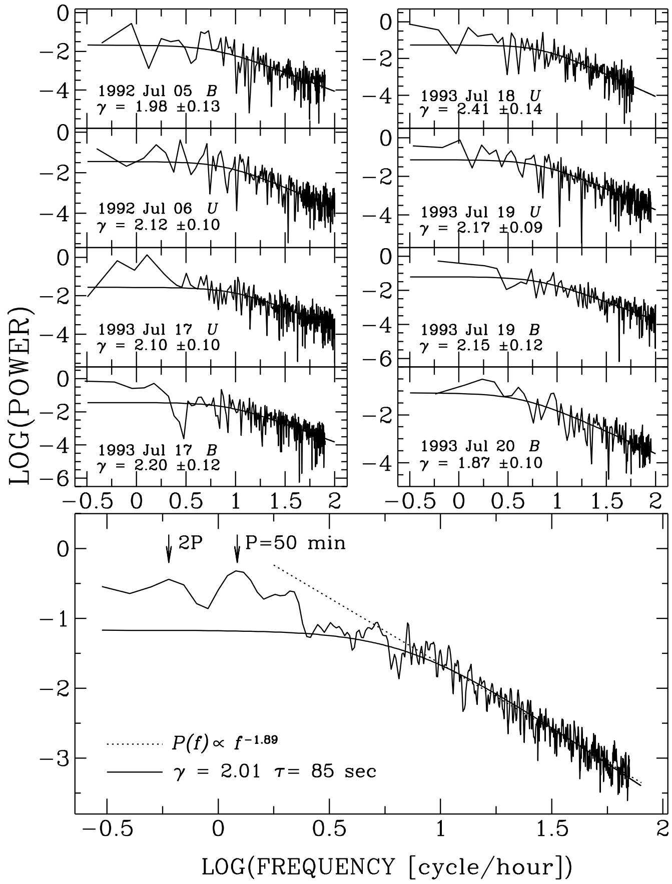

Fig. 5. Individual and mean PS of non-detrended runs fitted to function $\frac{\alpha}{1+(2\pi\tau f)^{\gamma}}$. τ was fixed as was determined by ACFs and by mean from the individual values of τ, respectively

may be an estimation of the correlation time. So we tried to fit the individual and the mean PS of non-detrended runs to function

$$P(f) = \frac{\alpha}{1 + (2\pi\tau f)^{\gamma}} \tag{3}$$

as τ was fixed to be equal to the correlation times determined by ACFs and the mean value, respectively. Because of the strong influence of the power due to the periodic variations, the mean PS was fitted only for frequencies $\log(f) \geq 0.4$. These fits are shown in Fig. 5. It is seen that the shape of the individual spectra and the tendency of the mean PS to become flat between frequencies $\log(f) = 0.4{-}1.0$ are fitted by the function (3). The power excess below $\log(f) = 0.4$ is due to the periodic variation. The values of γ found by the fits are given in Fig. 5 and are a little greater than those determined by fitting of the linear parts. Additionally, we used these fits to estimate the significance of the peaks in the PS as was discussed in Sect. 3. In this case only the peaks corresponding to "50 min" QPOs remain statistically significant.

The total amplitude of the flickering (i.e. the difference between the brightest and faintest points of the light curve) and standard deviation around the mean are listed in Table 4 also. There seems to be no difference between activity of the flickering in B and U bands if these quantities are taken as activity indication. Having an estimation of the total amplitude of the flickering we can calculate the contribution of the flickering light source to the total light of the star following the conception of Bruch (1992). The star brightness can be regarded as a sum of two sources - flickering light source and all other sources which are supposed to be constant on the flickering time scale. The magnitude of the constant light source can be defined as $m_{\rm c} = m + \Delta m/2$, where m is the mean magnitude of MV Lyr and Δm is the total amplitude of the flickering. Then, if the amplitude of the flickering is assumed to be independent of the passband, the ratio of the flux of the flickering light source $F_{\rm f}$ to that of the constant ones $F_{\rm c}$ over the whole optical range is given by

$$\frac{F_{\rm f}}{F_{\rm c}} = 10^{-0.4\Delta m'} - 1 \tag{4}$$

where $\Delta m' = m_0 - m_{\rm c}$ and m_0 is the magnitude of some point of the light curve. As m_c is an upper limit for the constant light source, the calculated by Eq. (4) ratios have to be regarded as a lower limit. In Table 4 are given the ratios of the fluxes calculated for m_0 equal to the mean and maximal star brightness. It is seen that flickering light source emits at least $0.2 - 0.4$ of the total radiation of the star.

Recently the most often discused mechanisms causing the flickering are turbulence in the accretions disc and/or unstable mass accretion on the white dwarf. These are stochastic processes and the resulting light curves would be described as a "shot noise". Although the flickering in cataclysmic variables is often discussed in terms of standard "shot noise" model (Williams & Hiltner 1984; Elsworth & James 1982; Panek 1980), it should be regarded only as a rough approximation. More complicated models should take into account the distribution of shot's durations which can change significantly the power spectra shape. Unfortunately, because of the overlapping of the shots, this distribution cannot be found from the light curves.

5. Discussion

The periods of statistically significant QPOs observed in MV Lyr vary about 50 min. Accepting system parameters $M_{\rm wd} = 0.7\,M_{\odot}$, $M_2 = 0.3\,M_{\odot}$ (Skillman et al. 1995) and $P_{\rm orb} = 0.1336^{\rm d}$ (Schneider et al. 1981) we found that at distances $r = 0.8 - 0.9\,R_{\rm RL}$ ($R_{\rm RL}$ is Roche lobe radius of white dwarf) the Keplerian periods are $P_{\rm K} = 43 - 54$ min. Therefore, if MV Lyr accretion disc extends to $0.8 - 0.9\,R_{\rm RL}$, its outer edge can be responsible for the observed QPOs.

Borisov (1992) suggested that "50 min" QPOs may be connected to the inhomogeneity motions at the disc outer edge induced by the gas stream from the red companion.

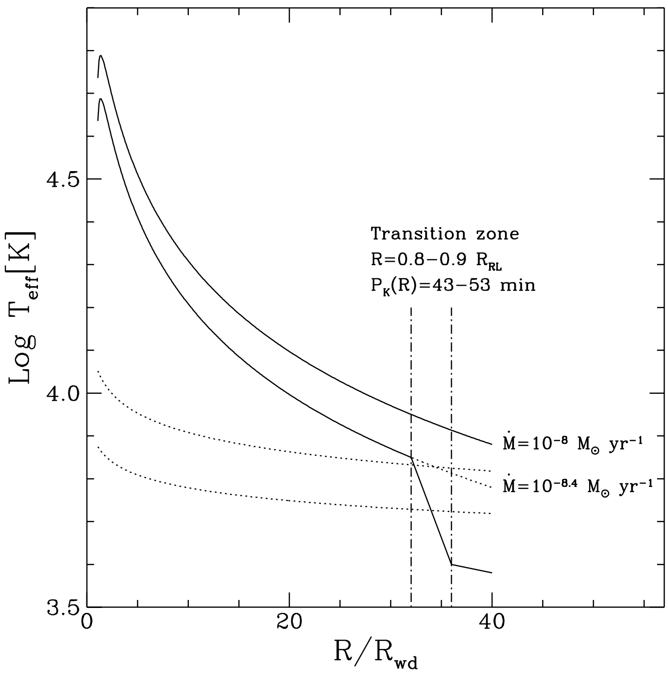

Fig. 6. Radial distribution of effective temperature in MV Lyr accretion disc (solid curves). The dotted curves point at $T_{\rm eff,max}$ and $T_{\rm eff,min}$ at which the disc changes its structure. The dashed-dotted lines limit the zone in which radial oscillations can be trapped

We tried to apply the model of the trapped oscillations developed by Yamasaki et al. (1995) and originally directed to explain observed QPOs in dwarf novae during the outburst. According to the thermal instability scenario, during the outburst the accretion disc consists of two parts with different physical conditions: a hot inner region where the hydrogen is fully ionized and an outer cool region in which the hydrogen is neutral. Between these two parts there appears a narrow transition zone where the hydrogen is partially ionized. Yamasaki et al. (1995) have shown by a linear analysis that there are modes of growing oscillations which are trapped just inside the transition zone and their period is approximately equal to the local Keplerian period. Since resulting brightness variations are sum of oscillations with close periods, large amplitude QPOs can be expected.

In active state VY Scl type novalikes contain hot accretion discs and typically exhibit relatively steady high mass transfer rate $\sim 10^{-8}\,M_\odot\,{\rm yr}^{-1}$. We assumed that in some of these systems the outer disc edge might be cool enough to allow recombination of the hydrogen and thus might play the part of the transition zone necessary for excitation of trapped oscillations. Further, the accretion rate that could cause partial recombination of the hydrogen in the outer part of MV Lyr accretion disc was estimated. According to Herter et al. (1979) the radial distribution of the disc effective temperature is

$$T_{\rm eff}(x) = T_0\, x^{-3/4}\,\left(1 - x^{-1/2}\right)^{1/4} \quad {\rm K}, \qquad (5)$$

where $x = r/R_{\rm wd}$, $R_{\rm wd}$ is white dwarf radius calculated according to Eggleton (1983) and

$$T_0 = 4.1\;10^4\,\dot{M}_{16}^{1/4}\,M_1^{1/4}\,R_{1,9}^{-3/4} \quad {\rm K}, \qquad (6)$$

$\dot{M}_{16}$ is mass transfer rate in units $10^{16}\,{\rm g\,s^{-1}}$, $M_1 = M_{\rm wd}/M_\odot$ and $R_{1,9}$ is white dwarf radius in units 10^9 cm. $T_{\rm eff,max}$ and $T_{\rm eff,min}$ at which accretion disc changes its structure were evaluated according to Cannizzo (1993). The results are shown in Fig. 6. It is seen that if the mass transfer rate is $\sim \dot{M} = 10^{-8.4}\,M_\odot\,{\rm yr}^{-1}$ the hydrogen in the outer disc parts ($r > 0.8\,R_{\rm RL}$) will be partially ionized and consequently one can expect generation of QPOs with periods of $43 - 54$ min, such as observed in MV Lyr.

In two of the runs (Jul. 05, 1992 and Jul. 20, 1993) periods longer than expected were detected. The length of these runs, however, is small and they cover $2 - 2.5$ cycles of "50 min" QPOs only. In this case period determination may be strongly affected by flickering, gaps in the runs and varying length and shape of the individual cycles. To understand the behaviour of the QPOs better, regular, long photometric observations are needed.

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