NOVA–LIKE VARIABLE MV LYR: THE RESULTS OF A PHOTOMETRIC MULTILONGITUDE CAMPAIGN

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The cataclysmic variable MV Lyr is nova-like variable, or "anti-dwarf nova". In 1979–1989 years this star similar to other "anti-dwarf novae" spent its time in a high brightness state ($B \simeq 12\overset{m}{.}5$) getting fainter by $2^m - 8^m$ sometimes and returning to the "on" stage. But later its behaviour became non-typical for these stars. The length of its first deep minimum was 10 years. The modern state is characterized by very strong outbursts and very frequent changes of the stages. The periods $0\overset{d}{.}128$ and $0\overset{d}{.}136$ were obtained for 1998 and 1999, respectively. We conclude about a possible relation between the photometric period and brightness.

INTRODUCTION

MV Lyr is one of the brightest cataclysmic variables in the northern sky. It was discovered by Parenago [1] in 1946 as a star with an irregular variability. However, many of its peculiarities had no explanation. It was classified as the nova-like subtype – a VY Scl-star, or "anti-dwarf nova". During the 1979–1989 years, MV Lyr – similar to other "anti-dwarf novae" – spent its time in a high brightness state ("on" stage, $B \simeq 12\overset{m}{.}5$), sometimes getting fainter by $2^m - 8^m$ ("off" stage, $B \simeq 18^m$) and returning to the "on" stage. But later its behaviour became non-typical for nova-like stars. The length of its first deep minimum was 10 years. In this state the outburst amplitude was $1^m - 4^m$. The main characteristics of its variability are the relatively stable intervals in the high and low states with a difference of about 5 magnitudes between states. The detailed description of the long-term photometric behaviour during 1951–1996 are presented in a review by Pavlenko & Shugarov [2] (see references in [2]) and some parameters of the system are in [3]. A longer-term light curve was compiled over 65 years by Kraicheva *et al.* [4]. The outburst in 1997 is described in [5].

The appearance of nova-like stars and, particularly, MV Lyr in the high brightness state is unpredictable: our experience has testified that the brightness of "ordinary" outbursts never reaches the brightness of the real "high" state in MV Lyr. Even the most powerful outbursts are fainter than the high state by 0.5 mag. Since 1994 MV Lyr changed its type of behaviour into a controversial type and we actively awaited a real "prolonged high" state. In 1998 when the brightness of MV Lyr jumped above the intermediate level which distinguishes an outburst from the "real" high state, we started a multilongitude photometric campaign. It was interesting to check: 1) how long such a high state would be lasting, 2) would the light variations be similar as those in the previous high state, or, furthermore, what other light variations could be observed?

OBSERVATIONS

Observations have been carried out using the Zeiss-600 and ZTE 1.25-m telescopes of the Crimean laboratory of the Sternberg astronomical institute, the 38-cm telescope of the Crimean Astrophysical Observatory, the Newtonian 30-cm telescope of the SAI student Observatory (Moscow) and the 44-cm Newtonian telescope of the Center of Backyard Astrophysics (California). The light detectors were CCD-cameras: ST-7 (Moscow, Crimea) and an unfiltered Cookbook 245 camera (California) and the multiplier tube (Crimea). Observations were performed with time resolutions of 16 seconds (California), 1.5 – 2 minutes for other CCD observations (in R-band of Johnson system) and 10 sec for the multiplier tube. The dead times between exposures were of about 13 seconds for the ST-7 and 6 seconds for the Cookbook 245. In total we obtained several thousand measurements over 68 nights in Moscow and in Crimea (1998: JD24450921–1115; 1999: JD2451302–1445) and

18 nights in California (JD2451403–1453). The comparison stars were used from [6] for Crimean-Moscow and GSC 3132:01048 for California data. The Moscow-Crimea data were reduced by using a code by V. Goransky.

THE LONG–TERM LIGHT CURVE

The light curve of MV Lyr over the last 25 years is shown in Fig. 1. The part of the curve in B-band (from 1979 till 1998) has been taken from [5]. The light curve in 1998–99 is plotted (R-band) accordingly our data. Over the first "low" state (1979–98) MV Lyr showed a sequence of relatively short dwarf-like outbursts of various amplitudes and durations (see [6]), they are superimposed on the level of quiet state ($B \sim 17^{m}_{.}5$). In 1989 this state was rapidly changed to the high one ($B \sim 12^{m}_{.}5$) that lasted until 1995. Then MV Lyr entered into the state that is different from its previous states: it displays a sequence of strong outbursts of near equal amplitudes ($4^m - 5^m$) that are larger than the larger outbursts of the first low state. Over our campaign (1998–99) MV Lyr displayed two bright outbursts (or, alternatively, one two-humped outburst).

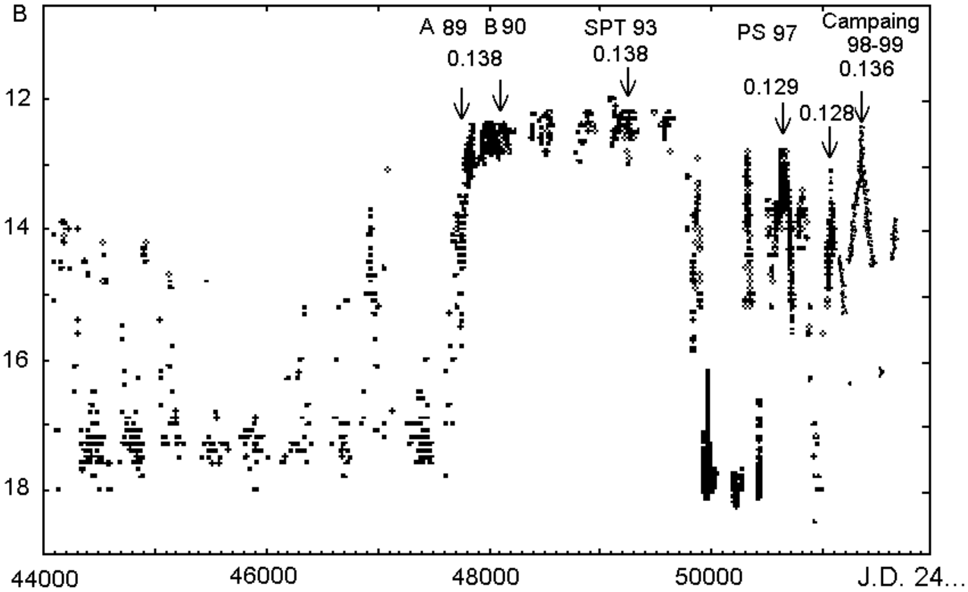

Figure 1: The overall light curve of MV Lyr during 1979–99. The magnitudes B (1979–97) and R (1998–99) are plotted versus Julian date. The arrows indicate the positions of intense observations: A89=[7], B90=[8], SPT93=[10], PS97=[5], 98–99=our campaign

THE SHORT–TERM VARIABILITY

The short-term variability (from minutes to hours) was observed every night. In Fig. 2 we present the several examples of the nightly light-curves for intermediate and a high level of brightness (photoelectric data by Shugarov and CCD data by Cook). The scale of x-axis is of about 4 hours, y-axis – 0.8 magnitudes.

The character of the periodic light variations in the vicinity of orbital period is still puzzling. The spectroscopic observations by Schneider *et al.* [9] and Skillman *et al.* [10] gave the $P_{orb} = 0^{d}_{.}133$. The photometric behaviours have been studied by several authors, but they have no a final explanation. Borisov [8] found the period $0^{d}_{.}1379$ observing this star at high level of the brightness and later Skillman *et al.* [10] confirmed the existence of this period for "on"-stage: $0^{d}_{.}1377$. This value was somewhat longer than the spectroscopic period and was interpreted as possible positive superhumps. Pavlenko and Shugarov [5] found the most likely periods for light variations at $0^{d}_{.}1294$ (or $0^{d}_{.}1487$). The first one seemed to be preferable as it was close to that for known NEGATIVE superhumpers. The second period was less likely because of it is placed far above the known empirical relation between the fractional period excess ($P_{sh} - P_{orb}$), where P_{sh} and P_{orb} are the superhump and orbital periods, respectively [12]. In 1998 we observed the star during the less strong outburst and in 1999 during the brighter outburst. Being in the bright state, MV Lyr displayed mean light variations from night to night of up to 0.5 mag. We carefully subtracted this trend from our data in order to find the near-orbital ($3^{h}_{.}2$) periodicity. More frequent photoelectric data were averaged within the CCD time resolution (1.5–2 min).

We constructed a power spectrum for the three sets of observations: 1) 1998 Crimean–Moscow CCD and photoelectric observations, 2) 1999 Crimean–Moscow CCD and photoelectric observations and 3) 1999 California CCD observations. Periodograms and data folded on these periods are shown in Fig. 3. The UPPER one corresponds to (1), the MIDDLE – to (2) and the LOWER periodogram – to (3). The most significant peak at

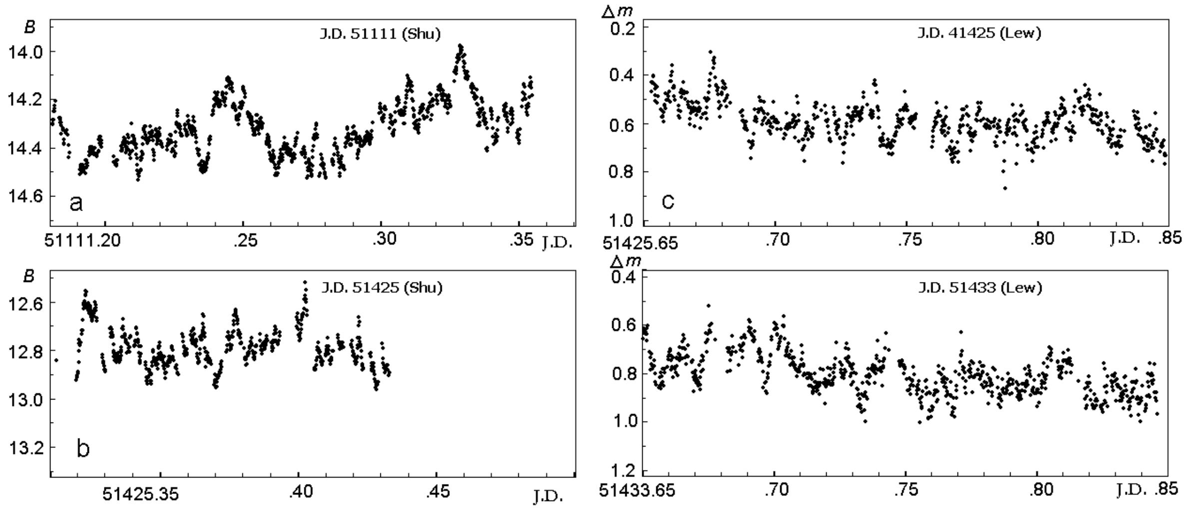

Figure 2: The examples of the short-term variability at the high level of brightness. Shu – photoelectric observations by Shugarov, Lew – CCD observations by Cook

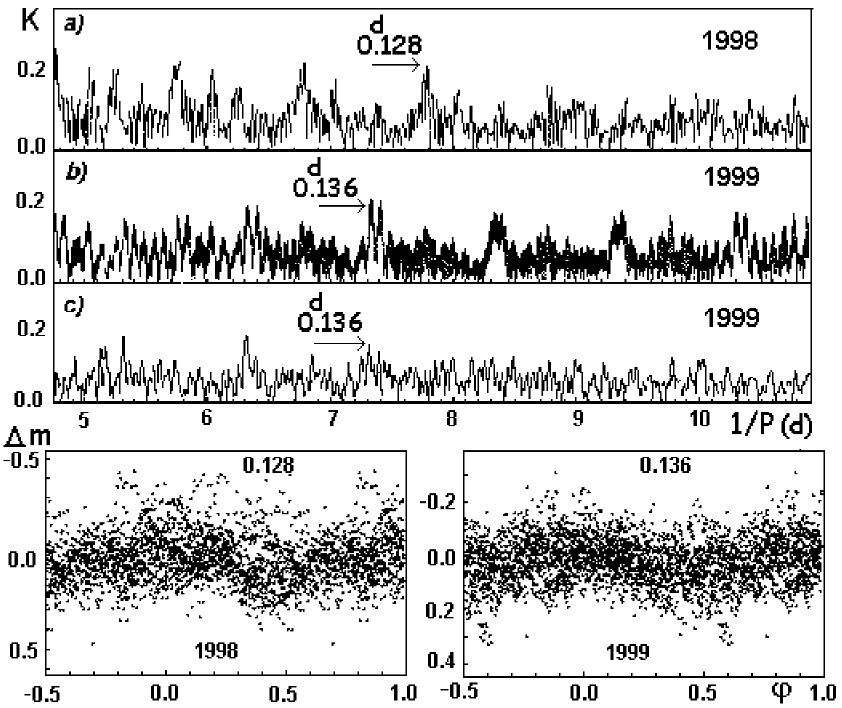

Figure 3: The power spectrum for MV Lyr for the intermediate and high level of brightness (above: a, b, c) and data folded on the best photometric period for 1998 and 1999 years, respectively (below)

the upper periodogram corresponds to the $0^d_.1281$. For 1999 the most likely period was $0^d_.1361$. The independent analysis of California data coincides with the Crimean–Moscow result, however, the one day alias harmonic $0^d_.14$ yields a more significant peak. The data folded on the indicated periods are shown below. It is seen the larger scattering on the light curves are caused by a fast (minute) variability.

DISCUSSION

We gathered all the available data to find the near-orbital light variations [5, 8, 10] and plotted them against the brightness of MV Lyr. The result is given in Fig. 4. It is seen that the photometric period decreases when the brightness decreases. Obviously, it can't be caused by the known decreasing of the superhump period for the SU UMa stars over the course of the superoutburst: the scale of superhump period decrease is smaller. There must be something going on in the disk at larger radius when the system is brighter – and the periodic variation is longer than when the system is fainter.

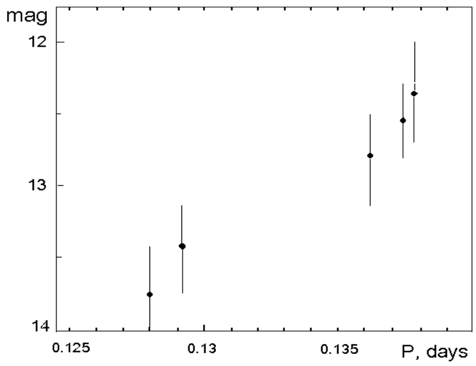

Figure 4: Magnitude versus the identified periods for quasi-periodic variations in MV Lyr. The bars signify the brightness range during intervals when each of the identified periodic variations was prominent

Future observations of this peculiar nova-like star are strongly recommended to study this relation. N. K., S. Sh. grateful for partial support of this work grants from RFBR (00–02–16471, 00–15–96553, 99–02–17589), Astronomy(1.4.2.2.) and Universities of Russia (991786).

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