POSITIVE AND NEGATIVE SUPERHUMPS OF THE DWARF NOVA MN DRA

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ABSTRACT. We present the result of O–C analysis of the dwarf nova MN Dra. It is based on the multi-site photometric observations that were made over 77 nights in August – November, 2009. The total exposure was 433 hours. During this time binary underwent two superoutbursts and five normal outbursts. In superoutbursts the positive superhumps decreased with extremely large $\dot{P} = -(3-8) \times 10^{-4}$ for SU UMa-like dwarf novae, confirming the known behavior of MN Dra in 2003.

MN Dra displayed large-amplitude (up to 1.4^m in quiescence and 0.1^m–0.2^m in normal outbursts) negative superhumps. The improved value of negative superhump period is 0.095952(4) d.

Key words: Binary, cataclysmic stars, superhumps: MN Dra.

1. Introduction

Dwarf novae are a subclass of cataclysmic variable stars whose systems consist of a late-type star that loses matter through its inner Lagrange point to a non-magnetic white-dwarf. Degenerate companion, first forming an accretion disk around it. SU UMa stars are the shortest-period systems among cataclysmic variables, with orbital periods in the range 80–180 min. SU UMa stars also differ from other cataclysmic variables with longer periods: exhibiting two kinds of outbursts:

(1) long-duration outbursts with amplitudes of 2^m–6^m that last approximately two or three weeks;

(2) fainter and shorter (3–5 days) outbursts.

The first type of outbursts is called superoutbursts and the second type, normal (or ordinary) outbursts. Short-period brightness variations, or positive superhumps, are observed during superoutbursts, whose periods are usually several percent longer than the orbital period. The positive superhumps have been successfully explained in the theory of tidal instability. They are caused by the apsidal precession of the accretion disk generated by gravitational perturbations of the secondary (Warner, 2005). Less common negative superhumps whose periods are slightly shorter then orbital period, are observed in a wide region of subclasses of cataclysmic variables (but only four dwarf novae have this property). The appearance of negative superhumps probably is caused by a retrograde precession of a tilted accretion disk (Montgomery and Bisikalo, 2010).

MN Dra was first discovered S.A. Antipin from the Moscow plate collection, and was originally designated as Var73 Dra (Pavlenko et al., 2010). To determine the nature of the variable it was observed in the Crimean Laboratory of the Sternberg Astronomical Institute in 2001. These observations confirmed that star is a dwarf nova, of the SU UMa type. Pavlenko et al. (2009) discovered in MN Dra the negative superhumps with period 0.0960 d.

2. Observations

Photometric observations were carried out in Crimean astrophysical observatory and Terskol observatory over 77 nights in August – November, 2009 in R band. The total exposure was 433 hours in integral light. Observations were done with a help of CCDs: FLI 1001E (Shajn 2.6-m telescope CrAO); PIXELVISION (60-cm telescope INASAN Terskol, Russia); SBIG ST-7 (38-cm telescope CrAO) and Zeiss 60-cm telescope in Crimean laboratory of the Sternberg astronomical institute. Total duration of observations was 433 hours (about 77 nights).

We reduced the obsevations in accordance with the aperture photometry technique using codes written by V.P. Goranskii and the MAXIM DL4 package. The accuracy of observations depended on the telescope used, the object's brightness and the weather conditions during the observations. We estimated its value from the brightness differences of several check stars relative to the comparison star. For the brightest state of the object and the brightness minimum, the accuracies were $0.^{m}007$–$0.^{m}03$. We used the comparison star with coordinates $20^h23^m35.358^s$, $+64^o36$ 56.66 (J2000.0) according to the USNO–A2.0 catalog (Monet et al., 2004).

3. General light curve

Our observations covered almost two supercycles including two superoutbursts and five normal outbursts (Fig. 1). The length of the supercycle was about 30 days. Typically three normal outbursts could occur during one supercycle. The amplitude of superoutbursts was $3^m.5$, its plateau lasts less that 10 d. The duration of normal outburst was rather long ($\sim$ 5 d) confirming those found by Antipin and Pavlenko (2002) and their amplitudes were in the range of 3^m–$3^m.5$ The scattering at plateau of superoutburst is caused by the positive superhumps and those in minimum – by the negative superhumps (Warner 1995).

3. O–C analysis

We determined the times of maxima for all positive and negative superhumps and analyzed their evolution separately. Note that negative superhumps have been seen both in normal outbursts and between them in minimum.

3.1 Positive superhumps

For the maxima of first and second superoutburst we obtained corresponded ephemeris as follows:

$$HJD_1Max = 2455023.28 + 0.105416 \cdot E \qquad (1)$$
$$HJD_2Max = 2455023.41 + 0.105416 \cdot E \qquad (2)$$

Using these ephemeris we calculated (O–C)s (see Fig. 2 and Fig. 3). It is seen that the period of positive superhumps for the first superoutburst decreases with

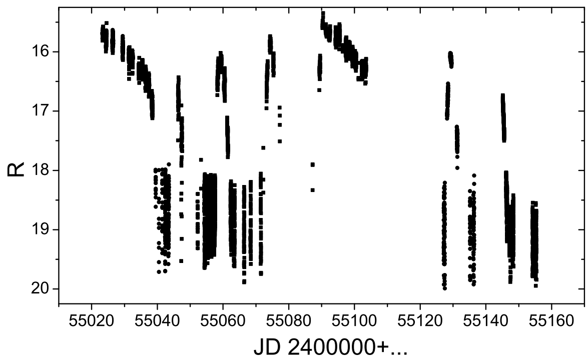

Figure 1: General light curve of MN Dra.

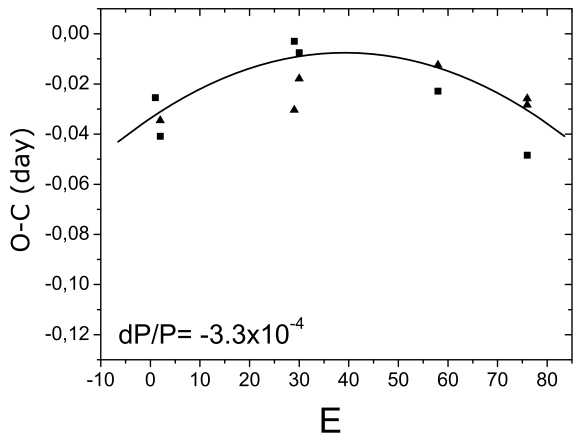

Figure 2: O–C diagram of the positive superhumps for the first superoutburst.

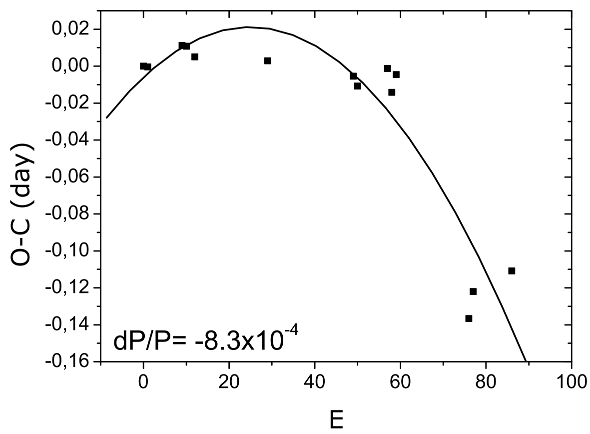

Figure 3: O–C diagram of the positive superhumps for the second superoutburst.

the $\dot{P} = -3.2 \times 10^{-4}$ during 80 cycles and for the second superoutbursts decreases with $\dot{P} = -8.3 \times 10^{-4}$ during 100 cycles. We could conclude that for both superoutbursts the rate of positive superhumps decrease is some different but coincides within the order of 10^{-4}.

3.1 Negative superhumps

Using ephemeris published by Pavlenko et al. (2010), we calculated O–C for all negative superhumps. The result is shown in Fig. 4. It is seen that the O–C behavior is rather complex. First is the long-term change that could be fitted by linear decrease. Using linear trend one could improve the initial period. The new value of the negative superhump period we obtained is 0.095952 d and corresponded ephemeris is:

$$HJDMax = 2454979.400(6) + 0.0959592(4)E \ (4)$$

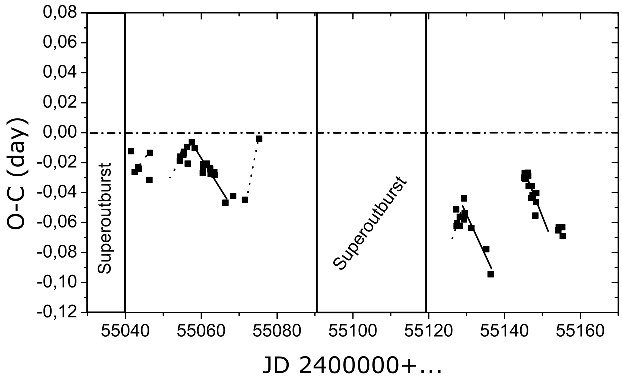

Figure 4: General diagram O–C.

Second, one could see that the O–C for maxima of negative superhumps vary cyclically in correlation with normal outbursts (see Fig. 4, 5). For comparison of time of outburst maxima and O–C maxima we drew vertical lines (the time of O–C maximum was obtained for intersection of fitting lines). Evidently, the times of these maxima do not coincide, and maximum O–C comes slightly before maximum of brightness MN Dra.

The O–C variations look like a jump switching of the period of negative superhumps from the longest value to the shortest one during the beginning of a normal outburst.

The O-C behavior could be even more complex. At some nights we got fast O–C variation: note the "bounced" but real $O - C = -0.3$ d in Fig. 6. This point is omitted in Fig.4.

4. Conclusion

Such correlation points to an impact of accretion on the period of negative superhumps. More observations are needed to understand the nature of this phenomenon.

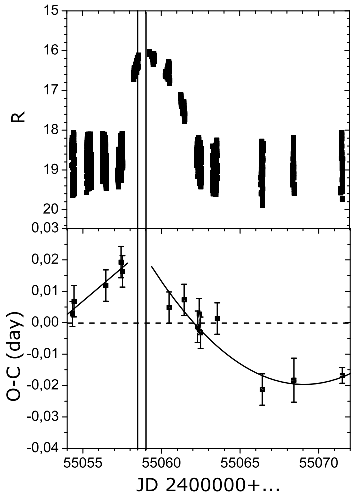

Figure 5: O–C of negative superhumps (lower part of figure) for one normal outburst (upper part of figure).

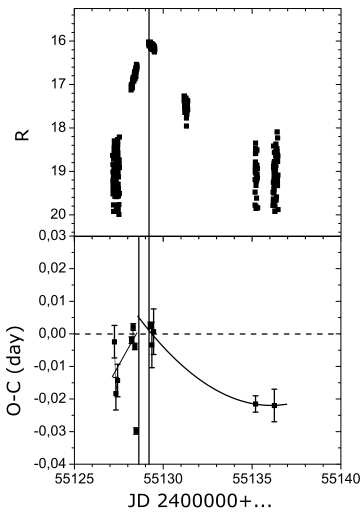

Figure 6: O–C of negative sperhumps (lower part of figure) for other normal outburst (upper part of figure).

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