Curious Variables Experiment (CURVE).

TT Bootis - superhump period change pattern confirmed.

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Abstract

We report extensive multi-station photometry of TT Boo during its June 2004 superoutburst. The amplitude of the superoutburst was about 5.5 mag and its length over 22 days. The star showed a small re-brightening starting around the 9th day of the superoutburst. During entire bright state we observed clear superhumps with amplitudes from 0.07 to 0.26 mag and a mean period of \( P_{sh} = 0.0779589(47) \) days (112.261 ± 0.007 min). The period was not constant but decreased at the beginning and the end of superoutburst yet increased in the middle phase. We argue that the complicated shape of the \( O-C \) diagram is caused by real period changes rather than by phase shifts. Combining the data from two superoutbursts from 1989 and 2004 allowed us to trace the birth of the late superhumps and we conclude that it is a rather quick process lasting about one day.

\textbf{Key words:} Stars: individual: TT Boo – binaries: close – novae, cataclysmic variables

1 Introduction

\( UBV \) photometry of TT Boo in quiescence was obtained by Szkody (1987). She found values of \( B-V = 0.38 \) and \( U-B = -1.09 \) mag, which are rather typical for dwarf novae of comparatively long periods but not for SU UMa stars which usually have \( B-V \) color around zero. Howell & Szkody
(1988) reported quiescent photometry of TT Boo and their observations revealed light variations with a period near 111 ± 5 min with an amplitude of 0.2 mag. They also mention the observations of Thorstensen and Brownsberger, who observed the star in the bright state and found features that looked like superhumps with a tentative period of 97 min. This is different from observations of Howell & Szkody (1988) because in all confirmed typical SU UMa stars the superhump period is slightly longer than the orbital period. Spectroscopy of TT Boo in the outburst was obtained by Bruch (1989).

More detailed observations of TT Boo in its bright state were performed during two nights of April 1993 by Kato (1995). He found clear superhumps with a period of 0.07811(5) days confirming that TT Boo belongs to the SU UMa-type dwarf novae class. Despite its quite frequent outbursts and brightness at maximum of $mV = 12.7$ mag, TT Boo is a poorly studied object. The best determination of the superhump period is based on only two nights of observations and the orbital period of the system is not known.

We were alerted to the ongoing outburst of TT Boo by Carlo Gualdoni’s VSNET outburst alert number 6316. He reported that on June 3.9792 UT the star was at magnitude 12.8.

2 Observations and Data Reduction

Observations of TT Boo reported in the present paper were obtained during two superoutbursts. Observations from August 1989 were collected at Dominion Astrophysical Observatory (DAO) Victoria B.C., Canada with the 1.22-m telescope equipped with an RCA-2 CCD camera. A Johnson V filter was used. The exposure times were 60 and 120 seconds on the first and second nights, respectively.

The data from 2004 were collected at two locations: the Ostrowik station of the Warsaw University Observatory and CBA Concord in the San Francisco suburb of Concord, approximately 50 km from East of the City. The Ostrowik data were collected using the 60-cm Cassegrain telescope equipped with a Tektronics TK512CB back-illuminated CCD camera. The scale of the camera was 0.76"/pixel providing a 6.5’ x 6.5’ field of view. The full description of the telescope and camera was given by Udalski and Pych (1992). The CBA data were collected using an f/4.5 73-cm reflector operated at prime focus on an English cradle mount. Images were collected with a Genesis G16 camera using a KAF1602e chip giving a field of view of 14.3’ x 9.5’. Images were reduced using AIP4WIN software (Berry and Burnell 2000).

In Ostrowik and CBA Concord the star was monitored in "white light" in order to be able to observe it also at minimum light of around 19 mag. We used two comparison stars: GSC 3047:313 (RA = 14h57m55.03s, Decl. = +40°45’17'”) and GSC 3047:41 (RA = 14h57m43.0s, Decl. = +40° 45’06’”). CBA Concord exposure times were 15, 20 and 30 seconds depending upon the brightness of the star. The Ostrowik exposure times were from 90 to 150 seconds during the bright state and from 150 to 240 seconds at minimum light. A full journal of our CCD observations of TT Boo is given in Table 1. In 2004, we monitored the star for 69 hours during 25 nights and obtained 3924 exposures. In 1989, during two nights, we collected 366 exposures and followed the star for a total time of 8.47 hours.

All the Ostrowik and DAO data reductions were performed using a standard procedure based on the IRAF\(^1\) package and profile photometry was derived using the DAophotII package (Stetson 1987).

\(^1\)IRAF is distributed by the National Optical Astronomy Observatory, which is operated by the Association of Universities for Research in Astronomy, Inc., under a cooperative agreement with the National Science Foundation.
The typical accuracy of our measurements varied between 0.004 and 0.11 mag depending on the brightness of the object. The median value of the photometric errors was 0.015 mag

3  General light curve

Figure 1 shows the general light curve of TT Boo during our 2004 campaign. The rough transformation to $V$ magnitude was made using the comparison star GSC 3047:313 ($RA = 14^h57^m55.3^s$, Decl.$ = +40^o45^17^", V = 12.862$, $B - V = 0.889$) and assuming that the $B - V$ color of TT Boo in
superoutburst is around zero (Bruch and Engel 1994). We additionally assumed that the sensitivity of our detector in "white light" roughly corresponds to Cousins R band (Udalski and Pych 1992) and used Caldwell et al. (1993) transformation between $B-V$ and $V-R$ colors.

CCD observations are marked with dots while the open square corresponds to the observation of Carlo Gualdoni from June 3/4 reported to VSNET. The star was caught by him at the very beginning of the superoutburst because AAVSO observations from June 1/2 found TT Boo below 17.5 mag. Thus we conclude that the superoutburst started on June 2 or 3.

![Photometric behavior of TT Boo during its 2004 superoutburst](image.png)

**Figure 1:** The general photometric behavior of TT Boo during its 2004 superoutburst. Our CCD observations are marked with dots and the open square represents the observation of Carlo Gualdoni reported to VSNET.

Our first observations taken on June 4 between 4:38 and 10:40 UT show a slight declining trend with slope of 0.04 mag/day. During the next seven nights the decline was much steeper with a slope of 0.096 mag/day. Around June 12/13 we noted a clear change of the slope value to 0.073 mag/day. Similar phenomenon is often observed in other SU UMa stars as was noticed and summarized by Kato et al (2003). Around 12 UT on June 21, TT Boo entered the final decline phase with slope of 1.015 mag/day reaching magnitude 18 around June 25. The entire superoutburst thus lasted 22-23 days. From June 22 to July 7 the star stayed at brightness of 18 mag and on July 9 it finally faded to its quiescent magnitude of around 19 mag.
Figure 2: The light curves of TT Boo from its 2004 June superoutburst. The ticks on the vertical axis are separated by 0.1 mag.
4 Superhumps

As shown in Fig. 2, superhumps were present in the light curve of the dwarf nova on all nights from June 4 till June 21 (HJD from 161 to 178). It is difficult to recognize them on June 22 when the star entered the final decline phase. On June 4 the superhumps have an amplitude of only 0.10 mag and a sinusoidal shape. This means that we caught TT Boo very close to the moment of birth of the superhumps. On June 5 the star flashed with fully developed characteristic tooth-shape modulations with amplitude of 0.26 mag.

The evolution of the amplitude of the superhumps and shape of the light curve is shown in Fig. 3. This plot shows nightly light curves of TT Boo phased with the corresponding period (see next sections) and averaged in 0.02-0.05 phase bins. One can clearly see that tooth-shaped and large amplitude variations were observed from June 5 to 10. Around June 11-12 (HJD 169-170) amplitude significantly decreased and the secondary humps at phase around 0.3-0.5 became visible.

Figure 3: Nightly light curves of TT Boo phased with the corresponding superhump period and averaged in 0.02–0.05 phase bins.
4.1 Power spectrum of 2004 data

From each light curve of TT Boo in superoutburst we removed the first or second order polynomial and analyzed them using ANOVA statistics with two harmonic Fourier series (Schwarzenberg-Czerny 1996). The resulting periodogram is shown in the upper panel of Fig. 4. The most prominent peak is found at a frequency of \( f_1 = 12.818 \pm 0.005 \) c/d, which corresponds to a period of \( P_{sh} = 0.078015(30) \) days (112.34 ± 0.04 min). The first harmonic of this frequency at \( f_2 = 25.74 \pm 0.03 \) c/d is also clearly visible.

![Figure 4: ANOVA power spectrum of the light curve of TT Boo from its 2004 superoutburst. Upper panel: power spectrum of the Original light curve. Lower panel: power spectrum of the prewhitened light curve.](image)

It was shown by Olech at al. (2004) that some of SU UMa stars (eg. IX Dra and ER UMa) also show modulations with their orbital periods during the entire superoutburst phase. To check if any other periodicity is present in the superoutburst light curve of TT Boo, we first removed the decreasing trend from our nightly observations and then grouped them into blocks containing 2-4 nights. Within the nights in one block the shape of the superhumps was similar. Then the data from each segment were fitted with the following sum:
rel. mag = A_0 + \sum_{j=1}^{4} A_j \sin\left(2j\pi t / P_{sh}^* + \phi_j\right)  \tag{1}

where $P_{sh}^*$ is the superhump period determined for each block independently. In the next step, this analytic relation was removed from the light curve of each block. The whole resulting light curve was again analyzed using ANOVA statistics with two harmonic Fourier series. The result is shown in lower panel of Fig. 4. This power spectrum is noisy with the highest peak (not exceeding the 3\sigma level) at frequency of \(12.818 \pm 0.007\) c/d, which looks like the residual of main superhump frequency rather than a real peak. Finally, we conclude that in the light curve of TT Boo in superoutburst we did not find any other frequency except that connected with superhumps.

Figure 5: Upper panel: The \(O - C\) diagram for superhump maxima observed in the 2004 superoutburst of TT Boo. Middle panel: Superhump amplitude changes during 2004 superoutburst of TT Boo. Lower panel: The light curve of TT Boo from its 2004 superoutburst after subtraction of the mean decline trend.
4.2 The $O - C$ analysis of 2004 data

To check the stability of the superhump period and to determine its value we constructed an $O - C$ diagram. We decided to use the timings of primary maxima, because they were almost always better defined than minima. In total, we were able to determine 35 times of maxima and they are listed in Table 3 together with their errors, cycle numbers $E$ and $O - C$ values.

The least squares linear fit to the data from Table 3 gives the following ephemeris for the maxima:

$$\text{HJD}_{\text{max}} = 2453161.76643(57) + 0.0779575(48) \cdot E$$

indicating that the mean value of the superhump period is equal to $0.0779575(48)$ days ($112.259 \pm 0.007$ min). This is in good agreement with the value obtained from the power spectrum analysis. Combining both our period determinations gives a mean value of the superhump period as $P_{sh} = 0.0779589(47)$ days ($112.261 \pm 0.007$ min).

The $O - C$ values computed according to the ephemeris (2) are listed in Table 3 and also shown in the upper panel of Fig. 5.

4.3 Period change pattern

Until the mid of 1990’s all members of the SU UMa group seemed to show only negative superhump period derivatives (Warner 1995, Patterson et al. 1993). This was interpreted as a result of disk shrinkage during the superoutburst, thus lengthening its precession rate (Lubow 1992). This picture became more complicated when the first stars with $\dot{P} > 0$ were discovered. Positive period derivatives were observed only in stars with short superhump periods close to the minimum orbital period for hydrogen rich secondary (e.g. SW UMa - Semeniuk et al. 1997, WX Cet - Kato et al. 2001a, HV Vir - Kato et. al 2001b) or for stars below this boundary (e.g. V485 Cen - Olech 1997, 1RXS J232953.9+062814 - Uemura et al. 2002).

The diversity of $\dot{P}$ behavior is well represented in the $\dot{P}/P$ versus $P_{sh}$ diagram shown for example in Kato et al (2003b) or Olech et al. (2003). This graph seems to suggest that short period systems are characterized by positive period derivatives, while these with longer period by negative period derivatives.

Recently Olech et al (2003) investigated the $O - C$ diagrams for stars such as KS UMa, ER UMa, V1159 Ori, CY UMa, V1028 Cyg, RZ Sge and SX LMi and claimed that most (probably almost all) SU UMa stars show decreasing superhump periods at the beginning and the end of superoutburst but increasing period in the middle phase.

The $O - C$ diagram obtained for TT Boo seems to confirm this hypothesis. The superhump period change is quite complex and the rough fitting of the parabolas to the following cycle intervals: 0–35, 47–112, 98–232 gives the period derivatives of $(-52.3 \pm 1.3) \times 10^{-5}$, $(12.3 \pm 4.8) \times 10^{-5}$ and $(-6.2 \pm 0.9) \times 10^{-5}$, respectively.

It is interesting that the period changes seem to be correlated with changes in the amplitude of the superhumps and variations of the brightness of the star. This is clearly visible in Fig. 5 which shows $O - C$ values, amplitude variations in time and the light curve from superoutburst after removing the mean long term decline.
Table 2: **TIMES OF MAXIMA IN THE LIGHT CURVE OF TT Boo DURING ITS 2004 SUPEROUTBURST.**

| Cycle number $E$ | $HJD_{\text{max}} - 2453000$ | Error | $O - C$ [cycles] |
|-----------------|-----------------------------|-------|------------------|
| 0               | 161.7550                    | 0.0020| −0.1466          |
| 1               | 161.8365                    | 0.0020| −0.1012          |
| 2               | 161.9144                    | 0.0020| −0.1019          |
| 13              | 162.7800                    | 0.0015| +0.0015          |
| 14              | 162.8668                    | 0.0015| −0.0133          |
| 15              | 162.9362                    | 0.0015| +0.0052          |
| 22              | 163.4810                    | 0.0015| −0.0064          |
| 35              | 164.4942                    | 0.0025| −0.0095          |
| 47              | 165.4290                    | 0.0020| −0.0184          |
| 48              | 165.5080                    | 0.0080| −0.0050          |
| 59              | 166.3645                    | 0.0015| −0.0183          |
| 60              | 166.4420                    | 0.0030| −0.0241          |
| 61              | 166.5212                    | 0.0017| −0.0082          |
| 73              | 167.4542                    | 0.0020| −0.0401          |
| 98              | 169.4125                    | 0.0025| +0.0799          |
| 99              | 169.4923                    | 0.0020| +0.1036          |
| 111             | 170.4308                    | 0.0015| +0.1422          |
| 112             | 170.5100                    | 0.0025| +0.1581          |
| 129             | 171.8350                    | 0.0030| +0.1546          |
| 141             | 172.7675                    | 0.0020| +0.1162          |
| 142             | 172.8440                    | 0.0015| +0.0975          |
| 143             | 172.9218                    | 0.0025| +0.0955          |
| 153             | 173.7015                    | 0.0018| +0.0971          |
| 154             | 173.7800                    | 0.0030| +0.1041          |
| 155             | 173.8550                    | 0.0040| +0.0661          |
| 167             | 174.7896                    | 0.0020| +0.0547          |
| 192             | 176.7297                    | 0.0022| −0.0587          |
| 205             | 177.7396                    | 0.0020| −0.1042          |
| 206             | 177.8166                    | 0.0018| −0.1164          |
| 207             | 177.8930                    | 0.0040| −0.1364          |
| 213             | 178.3592                    | 0.0040| −0.1562          |
| 214             | 178.4385                    | 0.0030| −0.1390          |
| 215             | 178.5142                    | 0.0030| −0.1680          |
| 218             | 178.7500                    | 0.0025| −0.1432          |
| 232             | 179.8290                    | 0.0040| −0.3024          |
4.4 Period change, phase shift or both?

The problem with tracing the period changes using $O-C$ diagrams is that slight and continuous phase shifts at constant period can mimic true period changes. In fact, exactly the same $O-C$ plots could be obtained for synthetic light curves in one case with constant period and time dependent phase shift and in another case with constant phases and period variation in time.

Most recently, Pretorius et al (2004) described the results of an extensive campaign on the new SU UMa-type variable SDSS J013701.06 -091234.9. In their $O-C$ diagram of superhump maxima they describe the behavior as consistent with a constant period during first week of superoutburst and continuous phase shift in later period. However, detailed inspection of the $O-C$ values from first part of the superoutburst seems to agree with scenario of decreasing period during first three days and increasing during next four.

It is interesting, that about a dozen days after maximal brightness the $O-C$ has a value of 0.5 indicating that at this moment light modulations could be classified as late superhumps. These late superhumps have a significantly shorter period than normal superhumps indicating that except for possible phase shifts, a clear change of the period occurred.

Do we observe late superhumps in 2004 superoutburst of TT Boo? The answer seems to be 'no'. The $O-C$ values at the termination of the superoutburst are around $-0.3$. Even changing the ephemeris (2) to a longer period, better describing the large amplitude superhumps observed between cycles 10 and 100, we obtain a phase shift between maxima only at the level of 0.35 cycle. As a trace of young late superhumps we can assume the modulations observed on June 22/23 when the star entered into the final decline phase (see next section for details).

Do we observe period change in late stages of TT Boo superoutburst? In this case, the answer seems to be 'yes'. First, the superhump period for nights with cycle numbers larger than 180 is shorter than the superhump period of the large amplitude superhumps observed at the beginning and in the middle of superoutburst (just as in case of SDSS J01370106 -091234.9). Second, if we group our observations into two night segments and calculate the superhump period for each of these segments we obtain a slightly decreasing pattern. A simple linear fit to the period values obtained for cycle number 100 and larger gives a slope of $(-6.6 \pm 2.5) \times 10^{-5}$, clearly consistent with a parabola fitting the times of maxima in the same cycle intervals, which gives a value of $(-6.2 \pm 0.9) \times 10^{-5}$.

It is now clear that the simple model with a shrinking disk as the cause of negative superhump period derivatives is no longer valid. A new model must contend with the following observational facts:

- complex superhump period change patterns as seen in TT Boo and other well observed SU UMa stars,
- extreme values of superhump period derivatives as observed for example in KK Tel (Kato et al., 2003b) and MN Dra (Nogami et al., 2003).
- no superhump period changes occur in some SU UMa stars (for example IX Dra - Olech et al., 2004)
5 Late superhumps

In August 1989 TT Boo was observed during two consecutive nights near the end of the superoutburst. Combining these data with observations from June 2004 allowed us to trace the birth of the late superhumps. The upper panel of Fig. 6 shows observations from June 21/22 and June 22/23 of 2004. When the star was at $V$ magnitude between 14.3 and 14.7, it showed clear modulations with an amplitude of 0.085 mag and only a weak trace of secondary humps. The first four arrows point the moments of maxima displayed in Table 3. The last two arrows are expected times of maxima computed based on the moment of maximum at $E = 218$ and period of $P = 0.0775$ days. One can clearly see that on June 22/23 the amplitude of the modulations did not change significantly in comparison with the previous night but the secondary humps became strong enough to show an amplitude similar to the main maxima.

What happens when the star fades to $V \approx 16$ mag can be seen thanks to the 1989 data shown
in the lower panel of Fig. 6. On August 4/5, when the star was at $V = 14.4$ mag we see the same behavior as in the corresponding stage of superoutburst from 2004. The arrows mark the positions of maxima of ordinary superhumps. The secondary humps are marginally visible. The amplitude of the modulations is about 0.1 mag. On the next night, when the star was at $V \approx 16$ mag, the amplitude increased to over 0.3 mag. The last three arrows on the lower panel of Fig. 6 show expected positions of ordinary humps maxima and in this case they coincide with the secondary maxima. Main maxima are thus shifted by 0.5 in phase in comparison with the previous night.

Summing up, the behavior of TT Boo in superoutbursts observed in 1989 and 2004 suggests that during last stage of plateau phase the period of superhumps decreases continuously producing a phase shift of about 0.3 in comparison with large amplitude superhumps observed in the beginning of the superoutburst. In this phase, we still can call the observed modulations ordinary superhumps, even in the case when the phase shift caused by a decrease of the period reaches a value of 0.5 as was observed in SDSS J013701.06-091234.9 (Pretorius et al. 2004). During the final decline stage, the amplitude of the secondary humps becomes comparable with the amplitude of main modulations, and within one day these secondary humps flash into large amplitude late superhumps. Thus the late superhumps are in fact shifted in phase by 0.5 but in comparison with ordinary superhumps observed at the end of superoutburst not with these seen at the beginning. A similar situation was observed in the well studied dwarf nova VW Hyi (Schoembs & Vogt 1980, Vogt 1983) where late superhumps appeared after the rapid decline phase and caused a beat phenomenon due to the combination with the orbital hump.

6 Summary

We described the results of the observations of TT Boo in two superoutbursts from 1989 and 2004. The main conclusions of our work are summarized below:

1. The amplitude of the 2004 June superoutburst was about 5.5 mag and lasted just over 22 days.

2. The star showed a clear rebrightening around 9th day of the superoutburst (see Kato et al. 2003a for more detailed discussion of such a phenomenon).

3. During two observed superoutbursts, we detected clear superhumps with a period of $P_{sh} = 0.0779589(47)$ days (112.261 ± 0.007 min) No other periodicity was detected.

4. The superhump period change is quite complex but has a decreasing period during the first and the end phase of the superoutburst with an increasing period in the middle stage.

5. Combining the data from two superoutbursts from 1989 and 2004 allowed us to trace the birth of the late superhumps and we conclude that it is a rather quick process lasting about one day.

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References

[1] Berry, R. and Burnell, J, 2000, The Handbook of Astronomical Imaging Processing, Willmann-Bell, Inc., Richmond, VA, USA.

[2] Bruch A., 1989, A&A Suppl. Ser., 78, 145

[3] Bruch A., Engel A., 1994, A&AS, 104, 79

[4] Caldwell J.A.R., Cousins A.W.J., Ahlers C.C., van Wamelen P., Maritz E.J., 1993, SAAO Circ., 15, 1

[5] Howell S.B., Szkody P., 1988, PASP, 100, 224

[6] Kato T., 1995, IBVS no. 4243

[7] Kato T., Masumoto K., Nogami D., Morikawa K., Kiyota S., 2001a, PASJ, 53, 893

[8] Kato T., Sekine T., Hirata R., 2001b, PASJ, 53, 1191

[9] Kato T., Nogami D., Moilanen M., Yamaoka H., 2003a, PASJ, 55, 989

[10] Kato T., Santallo R., Bolt G. et al., 2003b, MNRAS, 339, 861

[11] Kholopov P.N., Samus N.N., Frolov M. et al, 1998, Combined General Catalogue of Variable Stars, 4.1 Ed (II/214A)

[12] Lubow S.H., 1992, ApJ, 401, 317

[13] Meinunger L., 1966, Mitt. Veränderl. Sterne, 3, 113

[14] Nogami D., Uemura M., Ishioka R. et al., 2003, A&A, 404, 1067

[15] Olech A., 1997, Acta Astron., 47, 281

[16] Olech A., Schwarzenberg-Czerny A., P. Kędzierski, K. Złoczewski, K. Mularczyk, M. Wiśniewski, 2003, Acta Astron., 53, 175

[17] Olech A., K. Złoczewski, K. Mularczyk, P. Kędzierski, M. Wiśniewski, G. Stachowski, 2004, Acta Astron., 54, 57

[18] Patterson J., Bond H.E., Grauer A.D., Shafter A.W., Mattei J.A., 1993, PASP, 105, 69

[19] Pretorius M.L., Woudt P.A., Warner B., Bolt G., Patterson J., Armstrong E., 2004, MNRAS, in print, astro-ph/0405202

[20] Schoembs R., Vogt N., 1980, A&A, 91, 25

[21] Schwarzenberg-Czerny A., 1996, ApJ Letters, 460, L107

[22] Semeniuk I., Olech A., Kwast T., Należyty M., 1997, Acta Astron., 47, 201

[23] Shapley H., 1923, Harvard Coll. Obs. Bull. no. 791

[24] Stetson P.B., 1987, PASP, 99, 191

[25] Szkody P., 1987, ApJ Suppl. Ser., 63, 685
[26] Udalski A., Pych W., 1992, Acta Astron., 42, 28
[27] Uemura M., Kato T., Ishioka I. et al., 2002, PASJ, 54, 599
[28] Vogt N., 1983, A&A, 118, 95
[29] Warner B., 1995, *Cataclysmic Variable Stars*, Cambridge University Press