1998 Superoutburst of the Large-Amplitude SU UMa-Type Dwarf Nova WX Ceti

Taichi KATO, and Katsura MATSUMOTO
Department of Astronomy, Kyoto University, Sakyo-ku, Kyoto 606-8502
tkato@kusastro.kyoto-u.ac.jp, katsura@kusastro.kyoto-u.ac.jp

Daisaku NOGAMI
Hida Observatory, Kyoto University, Kamitakara, Gifu 506-1314
nogami@kwasan.kyoto-u.ac.jp

Koichi MORIKAWA
468-3 Satoyamada, Yakage-cho, Oda-gun, Okayama 714-1213
koichi@morikawa.org

and

Seiichiro KIYOTA
Variable Star Observers League in Japan (VSOLJ), 1-401-810 Azuma, Tsukuba, Ibaraki, 305-0031
skiyota@nias.affrc.go.jp

(Received 2001 June 11; accepted 2001 July 11)

Abstract

We observed the 1998 November superoutburst of WX Cet, a dwarf nova originally proposed as a WZ Sge-like system. The observation established that WX Cet is an SU UMa-type dwarf nova with a mean superhump period of 0.05949(1) d, which is 2.1% longer than the reported orbital period. The lack of early superhumps at the earliest stage of the superoutburst, the rapid development of usual superhumps, and the possible rapid decay of late superhumps seem to support that WX Cet is a fairly normal large-amplitude SU UMa-type dwarf nova, rather than a WZ Sge-type dwarf nova with a number of peculiarities. However, a period increase of superhumps at a rate $\dot{P}/P = +8.5 \pm 1.0 \times 10^{-5}$ was observed, which is one of the largest $\dot{P}/P$ ever observed in SU UMa-type dwarf novae. A linear decline of light, with a rate of 0.10 mag d$^{-1}$, was observed in the post-superoutburst stage. This may be an exemplification of the decay of the viscosity in the accretion disk after the termination of a superoutburst, mechanism of which is proposed to explain a variety of post-superoutburst phenomena in some SU UMa-type dwarf novae.

Key words: accretion: accretion disks — stars: cataclysmic variables — stars: dwarf novae — stars: oscillations — stars: individual (WX Ceti)

1. Introduction

Dwarf novae are a class of cataclysmic variables (CVs), which are close binary systems consisting of a white dwarf and a red dwarf secondary transferring matter via the Roche lobe overflow. The resultant accretion disk around the white dwarf is susceptible to various kinds of instabilities, and is a source of a rich variety of activities in CVs. The two most relevant instabilities are thermal and tidal instabilities, which are responsible for dwarf nova-type outbursts and superhumps, respectively [see te[cite.osa96Osaki(1996)]] for a review]. Systems having both low mass-transfer rates ($\dot{M}$) and low mass ratios ($q = M_2/M_1$) are susceptible to both thermal and tidal instabilities, and are called SU UMa-type dwarf novae [for a recent review of SU UMa-type stars and their observational properties, see te[cite.war95Warner(1995)]]."\cite{cite.war95Warner(1995)} Among SU UMa-type dwarf novae, there exists a small subgroup of WZ Sge-type dwarf novae [originally proposed by te[cite.bai79Bailey(1979)]]"\cite{cite.bai79Bailey(1979)}; see also te[cite.dow81Downes and Margon(1981)]]"\cite{cite.dow81Downes and Margon(1981)} and te[cite.odo91O'Donoghue et al.(1991)]]"\cite{cite.odo91O'Donoghue et al.(1991)} lists two dwarf novae, WX Cet and UZ Boo, which show very infrequent and large-amplitude outbursts, similar to those observed in WZ Sge. WZ Sge, itself, has a number of peculiar properties (e.g. the longest observed recurrence time of 33 years and the lack of normal outbursts) among dwarf novae. The WZ Sge-type phenomenon has been a long-standing problem, and several hypotheses have been proposed. Two historically representative ones are te[cite.osa95Osaki(1995)]]"\cite{cite.osa95Osaki(1995)} and te[cite.las95Lasota et al.(1995)]]"\cite{cite.las95Lasota et al.(1995)}; the former assumed extremely low quiescent viscosity, and the latter assumed the evaporation of the inner disk. Modern views on these theoretical models can be found in te[cite.mey98Meyer-Hofmeister et al.(1998)]]"\cite{cite.mey98Meyer-Hofmeister et al.(1998)} and te[cite.min98Mineshige et al.(1998)]]"\cite{cite.min98Mineshige et al.(1998)}. Since
WX Cet was selected as one of two relatives to WZ Sge by te[cite.bai79Bailey(1979)] ([cite.bai79Bailey(1979)]), this star has been receiving much attention.

t[cite.odo91O'Donoghue et al.(1991)] ([cite.odo91O'Donoghue et al.(1991)]) observed the 1989 June superoutburst of WX Cet, and detected superhumps with a period of \( \sim 80 \) m. te[cite.odo91O'Donoghue et al.(1991)] ([cite.odo91O'Donoghue et al.(1991)]) argued, from a similarity of photometric and spectroscopic features of WX Cet to other SU UMa-type dwarf novae, that there is no clear reason to retain the distinction between WZ Sge-type stars and other SU UMa-type dwarf novae. However, even if the argument by te[cite.odo91O'Donoghue et al.(1991)] ([cite.odo91O'Donoghue et al.(1991)]) against the clear observational separation of WZ Sge-type dwarf novae and SU UMa-type dwarf novae is partly supported by recent observations of other stars (e.g. 000 [cite.nog96Nogami et al.(1996); 000 [cite.bab00Baba et al.(2000)]), the 1989 June superoutburst of WX Cet was observed only under unfavorable seasonal condition, which made any detailed observation and analysis difficult. te[cite.men94Mennickent(1994)] ([cite.men94Mennickent(1994)]) performed a radial-velocity study in quiescence, and obtained a most probable orbital period (\( P_{\text{orb}} \)) of 79.16(4) min. te[cite.kat95Kato(1995)] ([cite.kat95Kato(1995)]) performed CCD photometry of the 1991 superoutburst, which again occurred in an unfavorable seasonal condition, and found that the rate of decline remarkably slowed down during the latter course of the superoutburst. te[cite.kat95Kato(1995)] ([cite.kat95Kato(1995)]) suggested some similarities to superoutbursts of WZ Sge, itself. More recently, te[cite.rog01Rogoziecki and Schwarzenberg-Czerny(2001)] ([cite.rog01Rogoziecki and Schwarzenberg-Czerny(2001)]) observed WX Cet in quiescence, and obtained a photometric period of 0.05827(2) d, which is in good agreement with the spectroscopic orbital period by te[cite.men94Mennickent(1994)] ([cite.men94Mennickent(1994)]), by one of the authors (TK). The Tsukuba observations were done using one of the authors (TK). The Tsukuba observations were done using an \( R_c \) filtered Bitran BT-20 camera attached to the Meade 25-cm Schmidt–Cassegrain telescope. The exposure time was 60–180 s. The images were analyzed using the MIRA A/P aperture photometry package. The Okayama observations were made using a V-filtered ST-7 camera attached to the Meade 25-cm Schmidt–Cassegrain telescope. The exposure time was 15–20 s. The images were analyzed using a microcomputer-based aperture photometry package originally developed by one of the authors (TK) and improved by KM. All observatories used GSC 5851.965 (Tycho-2 magnitude [1991] \( 59 \pm 0.05, \ B - V = + 0.67 \pm 0.09 \)) as the primary comparison star, whose constancy was confirmed using several fainter check stars in the same CCD images. The magnitudes of WX Cet were determined relative to GSC 5851.965. Barycentric corrections to observed times were applied before the following analysis. A failure of the clock adjustment was found in the Kyoto November 18 observation. A retrospective fine adjustment was made by maximizing the cross-correlation with the simultaneously taken Tsukuba data. The zero-point accuracy of the observed times of the Kyoto November 18 data is thus considered to be \( \sim 1 \) m.

Since each observer used a different filter, we first added a constant to each set of observations in order to obtain a common magnitude scale, which was adjusted to the most abundant Kyoto data. The constants were chosen to maximize the cross-correlation after the correction (table 1). Since outbursting dwarf novae are known to have colors close to \( B - V = 0 \), the difference in the systems would not significantly affect the following period analysis. The log of observations is given in table 2. Nightly averaged magnitudes listed in the table are corrected by constant offsets in table 1.

### 3. Results

#### 3.1. The Outburst Light Curve

The resultant light curve of the outburst is shown in figure 1. The light curve shows a long-lasting, slowly fading plateau phase, which is characteristic of an SU UMa-type superoutburst. The plateau phase lasted until 1998 November 24 (14 d after the detection of the outburst\(^1\)). The object then started fading quickly, and

\(^1\) This detection of the outburst can be approximately read as the start of the outburst, with an uncertainty of 1 d.
reached the post-outburst state on November 29, about ~2 mag above the quiescence. The object showed a gradual fade lasting until the end of the observation on December 10 (30 d after the detection of the outburst). Such a long, fading tail is considered as a relatively common, but not always exclusive, feature of WZ Sge-type stars (cite97Kato et al. (1997)).

### 3.2. Superhumps

Figure 2 shows an enlargement of the early part of the light curve. On the first night (November 11), the object showed little variation. On the next night (November 12), prominent superhumps developed.

We applied the Phase Dispersion Minimization (PDM) method (cite78Stellingwerf) to all of the data between 1998 November 12 and 25, after removing the slow trends of decline, and after prewhitening for slow variations with frequencies smaller than 2 d$^{-1}$.

The resultant theta diagram is shown in figure 3. The signal at the frequency 16.81 d$^{-1}$ corresponds to the

---

### Table 1. Magnitude offsets added to each set of observations.

| Date (1998) | Okayama data | Tsukuba data |
|-------------|--------------|--------------|
| November 11 | -            | -0.011       |
| November 12 | -            | -0.029       |
| November 13 | -0.292       | -            |
| November 14 | +0.310       | +0.051       |
| November 15 | +0.337       | -0.04        |
| November 17 | -            | -0.072       |
| November 18 | -            | -0.121       |
| November 19 | +0.199       | -            |
| November 20 | -            | -0.072       |
| November 21 | -            | -0.04        |
| November 22 | -            | -0.072       |

---

### Table 2. Log of observations.

| UT (start–end) | N$^*$ | Mag$^+$ | Error$^\dagger$ | Exp$^\parallel$ | Site$^\|$ |
|----------------|-------|---------|-----------------|----------------|--------|
| 1998 November  |       |         |                 |                |        |
| 11.437 – 11.591| 142   | 1.704   | 0.004           | 120 T          | T      |
| 11.462 – 11.592| 172   | 1.713   | 0.003           | 30 K           | K      |
| 12.399 – 12.656| 375   | 1.743   | 0.004           | 30 K           | K      |
| 12.430 – 12.690| 262   | 1.741   | 0.007           | 60 T           | T      |
| 13.468 – 13.703| 341   | 1.895   | 0.005           | 30 K           | K      |
| 13.516 – 13.557| 129   | 1.853   | 0.007           | 30 K           | K      |
| 13.557 – 13.607| 129   | 1.853   | 0.007           | 15 O           | O      |
| 14.385 – 14.697| 484   | 1.895   | 0.005           | 30 K           | K      |
| 14.439 – 14.561| 345   | 1.957   | 0.004           | 20 O           | O      |
| 15.366 – 15.677| 435   | 2.155   | 0.005           | 30 K           | K      |
| 15.412 – 15.646| 435   | 2.155   | 0.005           | 120 T          | T      |
| 15.427 – 15.579| 401   | 2.154   | 0.003           | 30 K           | K      |
| 15.462 – 15.700| 422   | 2.348   | 0.005           | 30 K           | K      |
| 17.582 – 17.660| 50    | 2.357   | 0.010           | 120 T          | T      |
| 18.360 – 18.713| 815   | 2.504   | 0.002           | 30 K           | K      |
| 18.557 – 18.668| 72    | 2.506   | 0.006           | 120 T          | T      |
| 19.367 – 19.707| 656   | 2.634   | 0.002           | 30 K           | K      |
| 19.532 – 19.657| 348   | 2.621   | 0.003           | 30 K           | K      |
| 20.362 – 20.648| 400   | 2.682   | 0.003           | 30 K           | K      |
| 20.465 – 20.479| 10    | 2.686   | 0.013           | 120 T          | T      |
| 22.448 – 22.688| 492   | 2.778   | 0.003           | 30 K           | K      |
| 23.358 – 23.687| 404   | 2.876   | 0.006           | 30 K           | K      |
| 24.512 – 24.687| 244   | 3.073   | 0.008           | 30 K           | K      |
| 24.578 – 24.655| 32    | 3.076   | 0.026           | 180 T          | T      |
| 25.367 – 25.678| 113   | 3.743   | 0.021           | 30 K           | K      |
| 25.528 – 25.646| 50    | 3.808   | 0.023           | 180 T          | T      |
| 26.377 – 26.680| 655   | 5.154   | 0.012           | 30 K           | K      |
| 29.349 – 29.657| 581   | 5.610   | 0.039           | 30 K           | K      |

* Number of frames.
† Magnitude relative to GSC 5851.965, corrected for table 1.
‡ Standard error of averaged magnitude.
∥ Exposure time (s).
§ Sites and filters: T = Tsukuba ($R_c$), O = Okayama ($V$), K = Kyoto (none).
mean superhump period ($P_{\text{SH}}$) of 0.05949(1) d. A slight asymmetry of the signal in the PDM analysis is mostly attributable to the asymmetry of the window function. The resultant superhump period gives a fractional superhump excess ($\epsilon = P_{\text{SH}}/P_{\text{orb}} - 1$) of 2.1% against cite.men94Mennickent(1994) and cite.rog01Rogoziecki and Schwarzenberg-Czerny(2001). Figure 4 shows the averaged profile of superhumps. The phase zero is taken as BJD 2451129.952 (1998 November 12). Figure 5 shows nightly averaged profiles of superhumps. The superhumps quickly grew in amplitude, and slowly decayed. The shifts of the superhump maxima toward negative phases represent the $O - C$ variation described in subsection 3.4. The superhumps became less prominent after $\sim 8$ d of the appearance of superhumps, but the amplitude grew again near the terminal stage of the superoutburst plateau. Such a regrowth of superhumps at the later stage was also observed in a large-amplitude SU UMa-type dwarf nova, V1028 Cyg, which cite.bab00Baba et al.(2000) considered as an intermediate object between usual SU UMa-type dwarf novae and WZ Sge-type stars.
3.3. Early Superhumps?

All of the superoutbursts of well-observed WZ Sge-type dwarf novae show semi-periodic modulations at the earliest stage of a superoutburst (000 cite.kat96Kato et al.(1996); 000 cite.mat98Matsumoto et al.(1998); 000 cite.kat98Kato et al.(1998)), which have the same, or extremely close, periods to $P_{\text{orb}}$. These modulations are called “early superhumps” (e.g. 000 cite.kat98Kato et al.(1998) 2). Although the origin of these modulations is not still perfectly understood, the exertion of a tidal instability on the accretion disk reaching the 3:1 resonance (the resonance responsible for the tidal instability) during the long quiescent states of WZ Sge-type stars is a promising explanation (000 cite.mey98Meyer-Hofmeister et al.(1998); 000 cite.min98Mineshige et al.(1998)). The presence of early superhumps can thus be considered to be one of the photometric criteria for WZ Sge-type stars. The data on November 11 (the first day of the observation) were examined. After removing the linear trend, the data were analyzed using the PDM. No significant signals were detected close to $P_{\text{orb}}$ or $P_{\text{SH}}$. Figure 6 shows the phase-averaged light curve of the November 11 data at the reported $P_{\text{orb}}$. No clear periodic signal was detected at this period. The upper limit of “early superhump”-type modulations was 0.03 mag.

3.4. $O-C$ Changes

We extracted the maxima times of superhumps from the light curve by eye. The averaged times of a few to several points close to the maximum were used as representatives of the maxima times. Thanks to high signal-to-noise, densely sampled data, the errors of the maxima times are usually less than $\sim0.002$ d. The resultant superhump maxima are given in table 3. The values are given to 0.0001 d in order to avoid the loss of significant digits in a later analysis. The cycle count ($E$) is defined as the cycle number since BJD 2451129.953 (1998 November 12.453 UT). A linear regression to the observed superhump times, disregarding late superhumps (discussed in the next 3.5), gives the following ephemeris:

$$\text{BJD(maximum)} = 2451129.9502 + 0.0594945E.$$  (1)

Figure 7 shows the $(O-C)$'s against the mean superhump period (0.05949 d). The diagram clearly shows the

---

2 This feature is also referred to as “orbital” superhumps or outburst orbital hump (000 cite.patetal98Patterson et al.(1998)).
Table 3. Times of superhump maxima.

| E* | BJD−2400000 | O−C† |
|-----|-------------|------|
| 0   | 51129.9531  | 0.0029 |
| 1   | 51130.0139  | 0.0042 |
| 2   | 51130.0744  | 0.0052 |
| 3   | 51130.1352  | 0.0066 |
| 18  | 51131.0242  | 0.0031 |
| 19  | 51131.0822  | 0.0016 |
| 23  | 51131.9707  | -0.0023 |
| 35  | 51132.0312  | -0.0013 |
| 36  | 51132.0916  | -0.0004 |
| 37  | 51132.1482  | -0.0033 |
| 50  | 51132.9176  | -0.0073 |
| 51  | 51132.9781  | -0.0063 |
| 52  | 51133.0346  | -0.0093 |
| 86  | 51135.0630  | -0.0037 |
| 87  | 51135.1195  | -0.0067 |
| 88  | 51135.1808  | -0.0049 |
| 100 | 51135.9018  | 0.0022 |
| 101 | 51135.9588  | -0.0003 |
| 102 | 51136.0189  | 0.0003 |
| 103 | 51136.0801  | 0.0020 |
| 104 | 51136.1383  | 0.0007 |
| 119 | 51137.0316  | 0.0016 |
| 120 | 51137.0930  | 0.0035 |
| 121 | 51137.1502  | 0.0012 |
| 134 | 51137.9292  | 0.0068 |
| 135 | 51137.9879  | 0.0060 |
| 169 | 51140.0038  | -0.0009 |
| 170 | 51140.0654  | 0.0012 |
| 171 | 51140.1223  | -0.0014 |
| 172 | 51140.1817  | -0.0015 |
| 187 | 51141.0718  | -0.0038 |
| 188 | 51141.1343  | -0.0008 |
| 204 | 51142.0942  | 0.0072 |
| 205 | 51142.1442  | -0.0023 |
| 235†| 51143.9447  | 0.0133 |
| 236†| 51144.0074  | 0.0165 |
| 237†| 51144.0880  | 0.0376 |
| 238†| 51144.1466  | 0.0367 |

* Cycle count since BJD 2451129.953.
† O−C calculated against equation 1.
‡ Late superhumps.

increase in the superhump period between $E = 0$ (1998 November 12) and $E = 140$ (November 20, 10 d after the outburst detection). This interval corresponds to the superoutburst plateau. The times of the superhump maxima in this interval can be well represented by the following quadratic equation:

$$
\text{BJD(maximum)} = 2451129.9558(10) + 0.059169(39)E + 2.52(29) \times 10^{-6}E^2.
$$

(2)

The quadratic term corresponds to $\dot{P} = +5.0 \pm 0.6 \times 10^{-6}$ d cycle$^{-1}$, or $P/P = +8.5 \pm 1.0 \times 10^{-5}$, which is one of the largest period derivatives ever observed in all SU UMa-type dwarf novae (000 [cite]cite.kat98Kato et al.(1998)).

3.5. Late Superhumps

During the final stage of a superoutburst and the subsequent post-superoutburst stages, some SU UMa-type dwarf nova show modulations having approximately the same period as $P_{\text{orb}}$, but having a maximum phase of $\sim 0.5$ offset from those of usual superhumps. This phenomenon is called “late superhumps” (000 [cite]cite.hae79Haefner et al.(1979); 000 [cite]cite.vog83Vogt(1983); 000 [cite]cite.vanderwoe88van der Woerd et al.(1988)). Figure 8 shows the nightly averaged profiles of variations. The time of phase zero and the period ($P_{\text{SH}}$) used in folding are the same as in figure 5. Note that the vertical scales are different between the panels. The relatively large error bars are a result of the faintness of the object. Superhumps at normal phases (around phase = 0) persisted on November 23, but became weaker on the next night. The signal became slightly stronger on November 25 (the rapid decline stage). A phase reversal was clearly observed on November 26, corresponding to the appearance of late superhumps. The signal likely persisted until November 29, but became weaker and more irregular on subsequent nights.

4. Discussion

4.1. Superhump Period Excess

The present observation provides a superhump period of 0.05949(1) d (average), best determined in the long research history of WX Cet. This period corresponds to a fractional superhump excess of ($\epsilon$) 2.1%. This value is moderately small among SU UMa stars (cf. 000 [cite]cite.pat98Patterson(1998)), but is substantially larger than those of some well-established WZ Sge-type dwarf novae: WZ Sge, $\epsilon = 0.8\%$ (000 [cite]cite.pat81Patterson et al.(1981)); AL Com, $\epsilon = 1.0\%$ (cf. 000 [cite]cite.nog97Nogami et al.(1997) for a comprehensive summary). Some WZ Sge-type dwarf novae (HV Vir, $\epsilon = 2.0\%$ (000 [cite]cite.kat01Kato et al.(2001)); EG Cnc [controversy exists; te]cite.kat97Kato et al.(1997) ([cite]cite.kat97Kato et al.(1997)) gives $\epsilon = 2.7\%$ while te]cite.patetal98Patterson et al.(1998) ([cite]cite.patetal98Patterson et al.(1998)) suggests $\epsilon=0.7\%$, however, seem to have similar $\epsilon$ to
that of WX Cet. Both analytical analysis (e.g. 000 [cite]cite.osa85Osaki(1985)) and numerical simulations (e.g. 000 [cite]cite.mur98Murray(1998)) suggest that $\epsilon$ is a good measure of the binary mass ratio $q$. With this regard, WX Cet is expected to have an intermediate binary parameters between (extreme) WZ Sge-type dwarf novae and SU UMa-type dwarf novae.

4.2. Early Superhumps

As described in subsection 3.3, the existence of early superhumps is one of the diagnostic features of WZ Sge-type dwarf novae. In the present observation of WX Cet, no evidence of early superhumps was observed. Even if the true maximum of the present superoutburst was missed by a day (only 1-d observational gaps existed before the outburst detection), the disappearance of early superhumps within two day from the start of the outburst makes a clear contrast to the week-long persistence of early superhumps in a WZ Sge-type star, AL Com (Ishioka et al., in preparation). Both the lack of a clear signal of early superhumps and the quick evolution of usual superhumps (subsection 3.2) are against the interpretation of WX Cet as a WZ Sge-type dwarf nova. A similar evolution of superhumps was also observed in V1028 Cyg (000 [cite]cite.bab00Baba et al.(2000)), a star which showed intermediate properties between the usual SU UMa-type dwarf novae and WZ Sge-type stars.

As introduced in subsection 3.3, recent theoretical studies suggest that the work of tidal instability during the long quiescence of WZ Sge-type dwarf novae is essential for the appearance of early superhumps. It is not surprising that early superhumps are the most discriminative feature of WZ Sge-type dwarf novae, since the long-lasting, large-amplitude superoutbursts of WZ Sge-type dwarf novae are regarded as a necessary consequence of a combination of low mass-transfer rates and the effective removal of the innermost accretion disk, which leads to an expansion of the accretion disk, eventually reaching the tidal instability (000 [cite]cite.mey98Meyer-Hofmeister et al.(1998); 000 [cite]cite.min98Mineshige et al.(1998)). From the lack of a clear signature of early superhumps, we consider WX Cet to be a fairly normal SU UMa-type dwarf nova with a large outburst amplitude, rather than a WZ Sge-type dwarf nova.

4.3. Period Changes

As shown in subsection 3.4, WX Cet showed a clear increase of the superhump period during the plateau stage of the superoutburst. Only a limited number of SU UMa-type dwarf novae are known to have such positive period derivatives (cf. 000 [cite]cite.kat98Kato et al.(1998); 000 [cite]cite.bab00Baba et al.(2000) and references therein). Since most of these systems are short $P_{orb}$ systems, there has been a suggestion that low $q$ and/or low $M$ are responsible for the phenomenon (000 [cite]cite.kat98Kato et al.(1998)). Recent discoveries of zero to marginally positive $P$ systems (V725 Aql: 000 [cite]cite.uem01Uemura et al.(2001); EF Peg: Matsumoto et al, in preparation) in long $P_{orb}$ systems more support that low $M$ is more responsible for the phenomenon. [Note, however, the peculiar, relatively high $M$ system V485 Cen is also known to show a positive $P$ (000 [cite]cite.ole97Olech(1997)). This may be an indication of the limit of our understanding of this phenomenon]. Although a positive $P$ is frequently met in WZ Sge-type systems, this may not be considered as a diagnostic feature.

4.4. Late Superhumps

In recent examples of well-observed WZ Sge-type stars (EG Cnc and AL Com), late superhumps (subsection 3.5) were observed to persist for more than tens of days after the termination of the main superoutburst (000 [cite]cite.kat97Kato et al.(1997); 000 [cite]cite.patat98Patterson et al.(1998); 000 [cite]cite.nog97Nogami et al.(1997)). Although the detection in the present observation was limited because of the faintness of the object, a clear decay of late superhumps within 4 d of the termination of the superoutburst (figure 8) suggests that large-amplitude late superhumps rather quickly decayed in this system. The time scale of the decay is roughly comparable to those in usual SU UMa-type dwarf novae (000 [cite]cite.hae79Haeffer et al.(1979)).
The origin of late superhumps is proposed to be modu-
lation of the properties of a precessing accretion disk
at the stream impact point (000 [cite]cite.hes92Hessman
et al.(1992)). While it is not still clear why this effect
persists longer in WZ Sge-type dwarf novae, a low $M$
may be responsible for delaying circularizing of the disk,
resulting in a persistence of the precessing accretion
disk. This may not be a direct discriminating feature of
WZ Sge-type dwarf novae, but apparently needs to be
examined in larger samples.

4.5. Quiescent Humps
tcite.rog01Rogoziecki and Schwarzenberg-
Czerny(2001) ([cite]cite.rog01Rogoziecki and
Schwarzenberg-Czerny(2001)) noted that the orbital
light curve showed alternations between single- and
double-hump profiles. tcite.rog01Rogoziecki and
Schwarzenberg-Czerny(2001) ([cite]cite.rog01Rogoziecki
and Schwarzenberg-Czerny(2001)) discussed the resemblance of this phenomenon with the similar alternations of humps in quiescent WZ Sge. Since the present work more strongly supports that WX Cet is a rather normal SU UMa-type dwarf nova with a large outburst amplitude, rather than an extreme WZ Sge-type star, such alternations of hump profiles in quiescence may not be a discriminative feature of WZ Sge-type dwarf novae. The presence of double humps may be better explained by the “reversed hot spot” hypothesis by tcite.men94Mennickent(1994) [cite]cite.men94Mennickent [see also tcite.men99Mennickent et al.(1999) ([cite]cite.men99Mennickent et al.(1999)) for an example of changing hump profiles in a low $M$ dwarf nova).

4.6. Rebrightening and the Late Decay Stage

There was no indication of a post-superoutburst rebrightening, which is often associated in short $P_{\text{orb}}$, SU UMa-type dwarf novae, especially in WZ Sge-type dwarf novae (cf. 000 [cite]cite.kat98Kato et al.(1998)), both in our observations and in visual observations reported to the VSNET Collaboration3.

The origin of post-superoutburst rebrightening in large-
amplitude SU UMa-type dwarf novae was proposed to be a reflection of cooling wave in the accretion disk (000 [cite]cite.how95Howell et al.(1995)). A more recent explanation includes the work by tcite.osa97Osaki et al.(1997) ([cite]cite.osa97Osaki et al.(1997), who assumed that the quiescent viscosity of the accretion disk is somehow maintained higher following a superoutburst than in quiescence. tcite.osa01Osaki et al.(2001) ([cite]cite.osa01Osaki et al.(2001)) further succeeded in reproducing a variety of post-superoutburst rebrightenings – from no rebrightening to multiple rebrightenings – by considering the competition between the thermal disk instability and the recently discovered mechanism of a decay of MHD turbulence under the condition of the low magnetic Reynolds numbers in the cold accre-
tion disk (000 [cite]cite.gam98Gammie and Menou(1998)). WX Cet showed a slow fading after the superoutburst (figure 1). This phenomenon may be an exemplification of a gradual decay of the disk viscosity, which determines the luminosity of the disk. Following tcite.osa01Osaki et al.(2001) ([cite]cite.osa01Osaki et al.(2001)), we suspect that the ignition of thermal instability accidentally failed to occur under competition with the decay of viscosity in the present post-superoutburst state of WX Cet. The post-superoutburst decline of WX Cet was almost perfectly linear (exponential), with a rate of 0.10 mag d$^{-1}$. Interestingly, this rate of decline is almost perfectly identical with the mean rate of decline (0.10 mag d$^{-1}$) during the plateau stage. Although this coincidence may be merely accidental, this may suggest the existence of a time scale for the decay of the disk viscosity related to the decay of the superoutburst plateau.

5. Conclusion

We observed the 1998 November superoutburst of WX Cet, a dwarf nova which had been proposed to be a related system to the peculiar dwarf nova WZ Sge. The observation established that WX Cet is an SU UMa-type dwarf nova with a mean superhump period of 0.05949(1) d. This period is 2.1% longer than the reported orbital period. This fractional superhump excess lies between those of extreme WZ Sge-type systems and those of other H04Ma-type systems. The lack of early superhumps at the earliest stage of superoutburst, together with the rapid development of usual superhumps, seems to disqualify WX Cet as being a WZ Sge-type dwarf nova. A period increase of superhumps with $P/P$ = $+8.5\pm1.0 \times 10^{-5}$ was observed during the superoutburst plateau. This is one of the largest $P/P$ ever observed in SU UMa-type dwarf novae. Although there was no evidence of a post-superoutburst rebrightening, a linear decline, with a rate of 0.10 mag d$^{-1}$, was observed in the post-superoutburst stage. This may be an exemplification of the proposed decay of quiescent viscosity following the superoutburst.

We are grateful to many amateur observers for supplying their vital visual and CCD estimates via VSNET, and especially to Rod Stubbings for his detection and early notification of the long-awaited superoutburst. Part of this work is supported by a Research Fellowship of the Japan Society for the Promotion of Science for Young Scientists (KMI).

References

[Baba et al.(2000)] Baba, H., Kato, T., Nogami, D., Hirata, R., Matsumoto, K., & Sadakane, K. 2000, PASJ, 52, 429
[Bayley(1979)] Bayley, J. 1979, MNRAS, 189, 41P
[Downes and Margon(1981)] Downes, R. A., & Margon, B. 1981, MNRAS, 197, 35P
[Gammie and Menou(1998)] Gammie, C. F., & Menou, K. 1998, ApJL, 492, L75
[Haefner et al.(1979)] Haefner, R., Schoembs, R., & Vogt, R. 1979, A&A, 77, 7
[Hessman et al.(1992)] Hessman, F. V., Mantel, K.-H., Barwig, H., & Schoembs, R. 1992, A&A, 263, 147
[Howell et al.(1995)] Howell, S. B., Skody, P., & Cannizzo, J. K. 1995, ApJ, 439, 337
[Kato(1995)] Kato, T. 1995, Inf. Bull. Var. Stars, 4256
[Kato et al.(1996)] Kato, T., Nogami, D., Baba, H., Matsumoto, K., Arimoto, J., Tanabe, K., & Ishikawa, K. 1996, PASJ, 48, L21
[Kato et al.(1998)] Kato, T., Nogami, D., Baba, H., & Matsumoto, K. 1998, in ASP Conf. Ser. 137, Wild Stars in the Old West, ed. S. Howell, E. Kunikkers, & C. Woodward (San Francisco: ASP), p. 9
[Kato et al.(1997)] Kato T., Nogami, D., Matsumoto, K., & Baba, H. 1997, (ftp://ftp.kusastro.kyoto-u.ac.jp/pub/vsnet/preprints/EG_Cnc/)
[Kato et al.(2001)] Kato, T., Sekine, Y., & Hirata, R. 2001, PASJ, submitted
[Lasota et al.(1995)] Lasota, J. P., Hameury, J. M., & Huré, J. M. 1995, A&A, 302, L29
[Matsunoto et al.(1998)] Matsunoto K., Nogami, D., Kato, T., & Baba, H. 1998, PASJ, 50, 405
[Mennickent(1994)] Mennickent, R. 1994, A&A, 285, 979
[Mennickent et al.(1999)] Mennickent, R. E., Sterken, C., Gieren, W., & Unda E. 1999, A&A, 352, 239
[Meyer-Hofmeister et al.(1998)] Meyer-Hofmeister, E., Meyer, F., & Liu, B. F. 1998, A&A, 339, 507
[Mineshige et al.(1998)] Mineshige, S., Liu, B., Meyer, F., & Meyer-Hofmeister, E. 1998, PASJ, 50, L5
[Murray(1998)] Murray, J. R. 1998, MNRAS, 297, 323
[Nogami et al.(1997)] Nogami, D., Kato, T., Baba, H., Matsumoto, K., Arimoto, J., Tanabe, K., & Ishikawa, K. 1997, ApJ, 490, 840
[Nogami et al.(1996)] Nogami, D., Kato, T., & Hirata, R. 1996, PASJ, 48, 607
[O'Donoghue et al.(1991)] O'Donoghue, D., Chen, A., Marang, F., Mittaz, J. P. D., Winkler, H., & Warner, B. 1991, MNRAS, 250, 363
[Olech(1997)] Olech, A. 1997, Acta Astron., 47, 281
[Osaki(1985)] Osaki, Y. 1985, A&A, 144, 369
[Osaki(1995)] Osaki, Y. 1995, PASJ, 47, 47
[Osaki(1996)] Osaki, Y. 1996, PASP, 108, 39
[Osaki et al.(2001)] Osaki, Y., Meyer, F., & Meyer-Hofmeister, E. 2001, A&A, 370, 488
[Osaki et al.(1997)] Osaki, Y., Shimizu, S., & Tsugawa, M. 1997, PASJ, 49, L19
[Patterson(1998)] Patterson, J. 1998, PASP, 110, 1323
[Patterson et al.(1998)] Patterson, J., Kemp, J., Skillman, D. R., Harvey, D. A., Shafter, A. W., Vanmunster, T., Jensen, L., Robert, F., Kiyota, S., Thorstensen, J. R., & Taylor, C. J. 1998, PASP, 110, 1290
[Patterson et al.(1981)] Patterson, J., McGraw, J. T., Coleman, L., & Africano, J. L. 1981, ApJ, 248, 1067
[Rogoziecki and Schwarzenberg-Czerny(2001)] Rogoziecki, P., & Schwarzenberg-Czerny A. 2001, MNRAS, 323, 850
[Stellingwerf(1978)] Stellingwerf, R. F. 1978, ApJ, 224, 953
[Stubbings(1998)] Stubbings, R. 1998, VSNET alert circular, 2357, (http://www.kusastro.kyoto-u.ac.jp/vsnet.Mail/alert2000/msg00357.html)
[Uemura et al.(2001)] Uemura, M., Kato, T., Pavlenko, E., Baklanov, A., & Pietz, J. 2001, PASJ, 53, 539