1. Introduction

Cataclysmic variables are semi-detached interacting binaries that consist of a white-dwarf primary and a late-type secondary. The secondary star fills its Roche lobe via the inner Lagrangian point (L1), by which an accretion disk is formed around the primary (for a review, see Warner 1995; Hellier 2001). Dwarf novae constitute a subclass of cataclysmic variables, further classified into three subclasses according to their activities (for a review, see Osaki 1996, 2005). SU UMa-type dwarf novae are one subclass of dwarf novae. They show two types of outbursts: a normal outburst that lasts for a few days, and a superoutburst that lasts for more than 10 days (Kato et al. 2004). During a superoutburst, tooth-like modulations, termed superhumps, are visible. The mean period of a superhump is about 3 days prior to an outburst. Although the working mechanism on this reddening is unclear, we propose two possibilities: one is that the inner portion of the accretion disk is filled by matter and obscures the central white dwarf; the other is that the stagnation effect works in the outer region of the accretion disk.

Key words: accretion, accretion disks — stars: dwarf novae — stars: individual (SU Ursae Majoris) — stars: novae, cataclysmic variables — stars: oscillations

Abstract

We report on simultaneous $g'$, $R_c$, and $I_c$ photometry of SU Ursae Majoris during 2011 December–2012 February using OAO/MITSuME. Our photometry revealed that quiescence is divided into three types based on the magnitude and color. Quiescent light curves showed complicated profiles with various amplitudes and time scales. Although no superoutbursts were observed during our run, five normal outbursts occurred with intervals of 11–21 d. The shapes of the normal outbursts were characteristic of the outside-in type. During the rising phase of a normal outburst, the light curve showed periodic modulations with a period of $\sim 0.048111(354)$ d, but the origin of this period was unclear. We examined daily averaged color–color diagrams, and found that two cycles exist. This implies that the thermal limit cycle in SU UMa is complicated. We newly discovered that $g' - R_c$ becomes red about 3 days prior to an outburst. Although the working mechanism on this reddening is unclear, we propose two possibilities: one is that the inner portion of the accretion disk is filled by matter and obscures the central white dwarf; the other is that the stagnation effect works in the outer region of the accretion disk.

OAO/MITSuME Photometry of Dwarf Novae. I.

SU Ursae Majoris

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mechanisms for generating negative superhumps are still being debated (Montgomery 2012b). In general, negative superhumps are known to be observed occasionally in ER UMa-type and novalike stars (Patterson et al. 1995; Ringwald et al. 2012; Ohshima et al. 2012). However, recent analyses reveal that negative superhumps are detected not only in these systems, but also in WZ Sge-type stars and typical SU UMa-type stars (Still et al. 2010; Kato et al. 2010, 2012). From the theoretical side, Montgomery (2012b) performed SPH simulations, and succeeded in reproducing accretion disks in SU UMa-type dwarf novae that tilt, warp, and precess in the retrograde direction. She concludes that negative superhumps and/or their signals should be ubiquitous below the period gap. Using the frequencies of negative superhumps, Osaki and Kato (2013) investigated Kepler data of V1504 Cyg, and concluded that the overall light curve is well reproduced by the thermal–tidal instability model.

Table 1. Log of observations for MITSuME telescope.

| Date       | JD (start) | JD (end) | N_g | N_r | N_i |
|------------|------------|----------|-----|-----|-----|
| 2011 Dec 1 | 897.2545   | 897.3259 | 145 | 142 | 139 |
| 2011 Dec 3 | 899.1490   | 899.3622 | 414 | 400 | 414 |
| 2011 Dec 4 | 900.0545   | 900.3462 | 477 | 479 | 478 |
| 2011 Dec 5 | 901.0121   | 901.3015 | 129 | 136 | 133 |
| 2011 Dec 6 | 902.3135   | 902.3448 | 61  | 63  | 61  |
| 2011 Dec 9 | 905.0096   | 905.1569 | 249 | 252 | 251 |
| 2011 Dec 10| 906.0426   | 906.2374 | 395 | 394 | 395 |
| 2011 Dec 11| 907.1033   | 907.2683 | 121 | 131 | 129 |
| 2011 Dec 12| 907.9916   | 908.3218 | 184 | 240 | 231 |
| 2011 Dec 13| 909.0216   | 909.1896 | 209 | 213 | 211 |
| 2011 Dec 14| 909.9876   | 910.3193 | 574 | 574 | 562 |
| 2011 Dec 15| 911.0066   | 911.0897 | 165 | 167 | 170 |
| 2011 Dec 16| 911.9881   | 912.3103 | 468 | 476 | 475 |
| 2011 Dec 17| 912.9852   | 913.3281 | 712 | 713 | 718 |
| 2011 Dec 18| 914.1411   | 914.3215 | 342 | 342 | 342 |
| 2011 Dec 19| 915.0139   | 915.3548 | 678 | 681 | 672 |
| 2011 Dec 20| 916.3229   | 916.3198 | 32  | 29  | 28  |
| 2011 Dec 21| 918.3166   | 918.3382 | 9   | 9   | 9   |
| 2011 Dec 22| 918.9800   | 919.3198 | 342 | 349 | 344 |
| 2011 Dec 23| 920.0332   | 920.3043 | 573 | 580 | 580 |
| 2011 Dec 25| 921.2649   | 921.3082 | 61  | 63  | 62  |
| 2011 Dec 26| 922.0261   | 922.3183 | 483 | 480 | 480 |
| 2011 Dec 27| 922.9783   | 923.2906 | 521 | 538 | 529 |
| 2011 Dec 28| 924.0758   | 924.1561 | 134 | 134 | 135 |
| 2011 Dec 29| 925.0257   | 925.1523 | 180 | 185 | 181 |
| 2011 Dec 30| 926.0530   | 926.3813 | 354 | 357 | 354 |
| 2012 Jan 4 | 930.9585   | 931.1378 | 340 | 339 | 338 |
| 2012 Jan 5 | 932.0321   | 932.2186 | 365 | 377 | 377 |
| 2012 Jan 6 | 932.9732   | 933.0944 | 257 | 256 | 255 |
| 2012 Jan 7 | 933.9873   | 934.3828 | 615 | 616 | 617 |

Table 2. Log of observations for Kagoshima 1m telescope.

| Date       | JD (start) | JD (end) | Exp | N |
|------------|------------|----------|-----|---|
| 2012 Mar 13| 1000.1499  | 1000.2802 | 45  | 194|
| 2012 Mar 14| 1001.0624  | 1001.2710 | 30  | 300|

* JD—2455000.
† Number of exposures.
‡ Number of exposures.
* JD—2455000.
† Exposure time in units of second.
‡ Number of exposures.

2013). Especially, V344 Lyr and V1504 Cyg have been well studied. Thanks to Kepler observations, researchers have been able to analyze the most sophisticated data ever obtained. For example, Cannizzo et al. (2010) and Cannizzo et al. (2012) examined various parameters of each outburst and intervals of quiescence, and concluded that the thermal–tidal instability model faces a difficulty in explaining quiescent intervals between normal outbursts during a supercycle. On the other hand, Osaki and Kato (2013) investigated Kepler data of V1504 Cyg, and concluded that the overall light curve is well reproduced by the thermal–tidal instability model. From an observational viewpoint, Kato et al. (2012) detected superhumps during a normal outburst just prior to a superoutburst of V1504 Cyg. Kato et al. (2012) also studied superhump period changes of these objects. In V344 Lyr, Kato et al. (2012) reported that a stage B–C transition may be associated with the secondary component of the superhumps that emerge from the middle of the plateau phase.

Kepler data of V344 Lyr and V1504 Cyg provide an additional scientific topic: the study of negative superhumps. Negative superhumps are considered to be a consequence of retrograde precession of a tilted accretion disk (Patterson et al. 1995; Montgomery 2009, 2012a). However, the physical mechanisms for generating negative superhumps are still being...
2. Observations

Simultaneous \( g' \), \( R_c \), and \( I_c \) photometry were performed from 2011 December 1 to 2012 February 20 using the 50 cm-MITSuME telescope located at Okayama Astrophysical Observatory (Kotani et al. 2005). A journal of the observations is given in table 1. The total datapoints of our run exceed 60000, which is the largest photometric campaign ever performed for SU UMa. On 2012 January 21 and 23, because the shutter of CCD in the \( g' \) band did not work very well, we excluded these data for period and color analyses.

After excluding bad data, we used 20191, 21459, and 20975 datapoints for the \( g' \), \( R_c \), and \( I_c \) bands, respectively. The obtained images were analyzed with aperture photometry using IRAF/daophot.\(^1\) We derived the magnitudes and colors of SU UMa with differential photometry using Tycho-2 4126-00036-1 (RA: 08:12:45.104, Dec: +62:26:17.57), whose constancy was checked by nearby stars in the same images. We adopted \( g' = 10.72 \), \( R_c = 10.41 \), and \( I_c = 9.98 \) as the magnitudes of a comparison star. These values may contain some errors, but such uncertainty will not influence the main results, because we focus on the variations of the light curves, and avoid estimating temperatures based on the color indices.

We also performed \( J \)-band photometry using the 1m-telescope of Kagoshima university. Table 2 gives a log of the \( J \)-band photometry. The exposure times were 30 s for 2012 March 13 and 45 s for 2012 March 14, respectively. To obtain a better \( S/N \), we summed two consecutive frames, so that substantial exposure times were 60 s and 90 s, respectively. Because of the narrow view of the telescope (5' x 5'), we could not use the same comparison star as that used in the optical. Instead we adopted 2MASS J081127.88+623842.3 (\( J = 13.039 \)) as a comparison star, whose constancy was checked by 2MASS J081123.76+623743.5 (\( J = 14.193 \)) and 2MASS J081124.05+623700.0 (\( J = 13.562 \)). Unfortunately, simultaneous optical–near infrared photometry could not be performed, because another observational schedule ran on MITSuME telescope. A heliocentric correction was made before any following analyses.

3. Results

3.1. Overall Light Curve

Figure 1 shows the obtained light curve of the \( R_c \) band. During our observations, SU UMa exhibited five normal outbursts at intervals of 11–21 days. According to the AAVSO light curve generator, a normal outburst occurred on 2011 November 30.\(^2\) Based on this observation, we safely regard a slight brightness that occurred on 2011 December 1 as being the declining stage of the normal outburst. It should be noted that the quiescent magnitudes in stages E, I, and K are obviously brighter by \( \sim 0.5 \) mag than those in other stages. We call stages E, I, and K “bright quiescence,” and stages A, C, and G “faint quiescence” throughout this paper. In addition, we briefly note that a flare-like event was observed on 2011 December 11, when the \( R_c \) magnitude varied from 15.5 to 14.5 at a rate of \( \sim 6.1 \) mag d\(^{-1} \). A similar phenomenon was reported by Echevarria et al. (1996) in which the magnitude changed drastically within a time scale of \( \sim 0.2 \) d (see figure 1a of Echevarria et al. 1996).

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\(^1\) IRAF (Image Reduction and Analysis Facility) is distributed by the National Optical Astronomy Observatories, which is operated by the Association of Universities for Research in Astronomy, Inc., under cooperative agreement with National Science Foundation.

\(^2\) (http://www.aavso.org/lcg).
3.2. Quiescence

Figures 2 and 3 display representative light curves and \( g' - I_c \) variations during faint and bright quiescences, respectively. As can be seen in these figures, the light curves show incoherent profiles with various time scales and amplitudes. It also should be noted that the maxima of the magnitude coincide with the blue peaks of \( g' - I_c \). This is in contrast with that observed during superhumps, during which the bluest peak in \( g' - I_c \) was prior to \( R_c \) by a phase of ~0.2 (Matsui et al. 2009; Imada et al. 2012).

In order to search for periodic signals in the light curves, we used the phase dispersion minimization method (PDM: Stellingwerf 1978) for light curves after removing a long trend. Figure 4 shows the results of PDM analyses. As can be seen in this figure, these theta diagrams imply many periodicities. In this section, we focus on periods around the orbital period of the system (\( P_{\text{orb}} = 0.07635 \) d, Thorstensen et al. 1986). Table 3 lists candidate periods around the orbital period. In order to clarify the origin of these periodicities, we folded light curves and \( g' - I_c \) variations with the periods listed in table 3. An example of the results is shown in figure 5, in which hump-like modulations are visible. However, we could not find robust evidence for negative superhumps, whose profiles show a slow rise and rapid decline in their light curves (Osaki & Kato 2013).
Regarding positive superhumps, a hint of them was shown in some folded light curves, though no phase discord between light curves and colors were observed.

3.3. Outburst

During our run, SU UMa experienced five normal outbursts, of which three (stages B, D, and J) were well observed. The overall profiles of these outbursts resemble those of type-A (outside-in) outburst (Smak 1984). The declining rates of these normal outbursts were estimated to be $\sim 1$ mag d$^{-1}$, typical for those observed in SU UMa-type dwarf novae (Olech et al. 2004).

We performed PDM analyses during the normal outbursts. Figure 6 shows the resultant theta diagrams applied to the fading stages of each normal outburst. During stage D, we
Fig. 7. Phase-averaged $R_c$ band light curve (filled circles) and $g'-I_c$ (filled squares) folded with 0.078365 d. A rapid rise and slow decline, reminiscent of superhumps, are visible in the light curve. On the other hand, no significant variations are visible in $g'-I_c$.

Fig. 8. $R_c$ light curve (filled circles) and $g'-I_c$ variation (open circles) on 2011 December 14, at the very onset of a normal outburst. Hump-like modulations with an amplitude of $\sim$0.3 mag are visible in the light curve.

Fig. 9. PDM analysis for the light curve on 2011 December 14 after removing the trend. The strongest signal corresponds to $P=0.048111(354)$ d. This periodicity can be checked with simple eye estimation of the light curve.

Fig. 10. $J$-band light curves of SU UMa obtained with KU 1 m. The $x$ and $y$ axes denote fractional time (unit in day) and relative magnitude, respectively. Although the datapoints contain large error bars, hump-like modulations are detectable in both light curves. Each datapoint is arbitrarily shifted for display purpose.

reported on the detection of superhumps in a previous letter (Imada et al. 2012). As for stage J, a hint of superhumps was observed with a period of $P = 0.078365(295)$ d. We folded the light curve and $g'-I_c$ color with this period. Figure 7 exhibits the resulting data. Although the phase-averaged light curve is reminiscent of superhumps, no significant color variations were found.

Figure 8 illustrates the enlarged light curve and color on 2011 December 14, corresponding to the onset of an outburst (stage B). One can notice cyclic variations with amplitudes of $\sim$0.3 mag. During the rising stage, the magnitude brightened at a rate of $-1.4(1)$ mag d$^{-1}$. This value is unusually smaller compared with those observed in other SU UMa-type dwarf novae ($-6$ mag d$^{-1}$, Warner 1995). Judging from the obtained value, the rising rate may have changed after our observation. After removing the rising trend, we performed a period analysis for the residual light curve. The resultant theta diagram is displayed in figure 9, from which we derived $P = 0.048111(354)$ d as a candidate period. This periodicity can be checked by a simple eye-estimation of the light curve. We also tried to examine the rising phase of stage J, but noisy data prevented us from conducting a period analysis.

3.4. $J$ Band Photometry

Figure 10 gives all of the $J$-band light curves of SU UMa. Although the data were acquired under a low $S/N$, hump-like modulations with an amplitude of $\sim$0.2 mag were visible. The mean magnitudes were estimated as $J = 13.36$ mag for 2012 March 13 and $J = 12.11$ mag for 2012 March 14, respectively. A hint of a rising trend was observed on 2012 March 13, when the magnitude varied at a rate of $-1.9(1)$ mag d$^{-1}$. According to the AAVSO light curve generator, the visual magnitudes yield $V = 14.0$ on 2012 March 13, $V = 12.3$ on March 14, and $V = 14.6$ on 2012 March 18, respectively. These results indicate that our $J$-band photometry was performed at the onset of the normal outburst.
4. Discussion

4.1. Color–Color Diagram

Figure 11 displays the daily averaged color–color diagram of SU UMa. As can be seen in this figure, bright quiescence tends to show redder $g' - R_c$ and bluer $R_c - I_c$ compared with those of faint quiescence. In addition, one can notice a “gap” at a threshold of $g' - R_c \sim 0.28$, which indicates that the magnitude in the $g'$ band becomes more faint than that in the $R_c$ and $I_c$ bands. It also should be noted that all datapoints of $g' - R_c$ during bright quiescence are located on the red side of the gap.

In order to further understand the color–color diagram, we investigated each datapoint of faint quiescence. We found that, (1) after the end of an outburst, color indices of $g' - R_c$ tended to be located on the blue side of the gap, although there existed exceptions, and (2) from a few days prior to an outburst, color indices of $g' - R_c$ were located on the red side of the gap, without exceptions. Taking these facts into account, we can draw the evolutions of the color indices, which are given in figure 12. Based on this diagram, we find two cycles: outburst $\rightarrow$ faint quiescence with bluer $g' - R_c$ $\rightarrow$ faint quiescence with redder $g' - R_c$ $\rightarrow$ outburst (marked with solid arrows) and outburst $\rightarrow$ bright quiescence $\rightarrow$ outburst (marked with a dashed arrow). The absence of data in the gap implies that a typical time scale of the transition from the blue to red side is as short as 1 day. The coexistence of the cycles suggests that the thermal equilibrium curve of the disk instability model is more complicated, such as figure 2 of Mineshige and Osaki (1985), compared with that of the simple S-shaped curve.

Recently, Price et al. (2007) performed extensive $V$ and $I_c$ photometry of the prototypical dwarf nova SS Cyg, and reported that there is a hint of a variation in the $V - I_c$ color was observed 5 days prior to an outburst. Although we used the $g'$, $R_c$, and $I_c$ bands, we confirmed a color variation prior to the outburst, as suggested by Price et al. (2007). In the present study, we found that, at least SU UMa itself, the values of the color indices are a powerful indicator for expecting an impending outburst.

Why is the $g'$ band faint before an outburst? One possibility is that the inner portion of the accretion disk is filled by matter, which obscures the flux from the white dwarf. If this is the case, then line profiles in the Balmer series, such as H$\beta$ and H$\gamma$, should change before an outburst; the wing velocities will increase because of the existence of inner matter. Another possibility is that the stagnation effect, originally propounded by Mineshige (1988), works in the accretion disk. Mineshige (1988) predicted that the outer cool region makes a halt in a warm state with $T_{\text{eff}} \sim 6000$ K at the onset of type-A outbursts. If the stagnation stage occurs prior to an outburst, this can bring $g' - R_c$ to a redder side of the color–color diagram. In order to clarify the nature of the faintness in the $g'$ band, spectroscopic observations prior to an outburst should be performed.

4.2. Quiescence

One of the most significant findings in our observations is that we confirm the presence of bright quiescence in SU UMa, itself. It is well known that, after the end of a superoutburst, SU UMa-type dwarf novae keeps brighter magnitudes compared with those of the majority of quiescence (Patterson et al. 1998; Sterken et al. 2007). This trend can also be seen in the Kepler data of V344 Lyr and V1504 Cyg, although there exist some exceptions (Cannizzo et al. 2010; Osaki & Kato 2013). Cannizzo et al. (2010) noted that this is associated with cooling of the white dwarf heated by a superoutburst (Sion 1995), although the slow decay in V344 Lyr for about 50 days after a superoutburst mentioned in Cannizzo et al. (2010) might be due to a purely instrumental effect accompanied by a repositioning of the Kepler spacecraft (see subsection 2.1 in Cannizzo et al. 2012). Bullock et al. (2011) suggested that the white dwarf of GW Lib was heated by the 2007 superoutburst, and has not yet returned to the quiescent state. Therefore, one can expect that the appearance of bright quiescence is restricted in the vicinity of the termination of the superoutburst.

The present observations, however, show that the appearance of bright quiescence is independent of the superoutburst. In
addition, the durations of bright quiescence tend to be shorter compared to those of faint quiescence. Although the reason for entering bright quiescence should await further observations, it may be attributed to the accretion disk, itself, rather than the heated white dwarf.

Regarding light curves, they show complicated profiles with various time scales and magnitudes. As mentioned in the previous section, no significant signals corresponding to the orbital period were detected in the PDM analyses. This implies that the main light source may have originated from a complicated structure of the accretion disk, rather than a hot spot. Color variations and light curves correlate well with each other: the maxima of the light curves coincide with the blue peaks of $g' - I_c$. This differs from those observed in superhumps, in which the blue peaks of $g' - I_c$ are prior to the bright maxima of the $R_c$ band by phase $\sim 0.2$ (Matsui et al. 2009; Imada et al. 2012). Matsui et al. (2009) noted that such behavior is associated with heating and expansion in the accretion disk. From this standpoint, the present result implies that these processes are marginal during quiescence.

4.3. Outburst

As noted in the previous section, SU UMa exhibited five normal outbursts during our observations. Bright maxima occurred on 14, 35, 46, 63, and 77 d from the epoch of our observations, by which we roughly estimated recurrence times of 21, 11, 17, and 14 d. According to the original thermal–tidal instability, the recurrence time of a normal outburst increases with the supercycle phase (Osaki 1989). However, the present observations show that no regularity exists in the recurrence times of the normal outbursts. A similar trend can also be seen in the Kepler light curves of V344 Lyr and V1504 Cyg, in which the duration of quiescence ranges from 3 d to 20 d. So far, our obtained data cannot lead to any conclusion about why SU UMa shows various durations of quiescence.

As displayed in figure 8, we succeeded to observe the very onset of the outburst, in which the light curve showed hump-like modulations with a period of 0.048111(354) d. If these modulations are linked to the Keplerian motion of the accretion disk, then the light source originated from $\sim 0.7 a$, where $a$ denotes the binary separation. This value is far beyond the tidal truncation radius of the accretion disk of SU UMa. It is unlikely to be the case either that these are associated with the hot spot, since no sign of the orbital period is detected. At present, the origins of the modulations and the periodicity are unclear. In order to clarify the physical mechanism of these modulations, further photometric data before the onset of an outburst should be collected.

4.4. Negative Superhumps

One of the purposes of our observations is to study negative superhumps of SU UMa-type dwarf novae. As noted in the previous section, our PDM analyses imply signals shorter than the orbital period of the system. Osaki and Kato (2013) noted that negative superhumps show coherent light curves with a slow rise and a rapid decline, like figure 8 of their paper. Wood et al. (2011) reported that the appearance and disappearance of negative superhumps may be triggered by an outburst, based on period analyses on V344 Lyr. In conjunction with these results, it may be premature to conclude that we detect negative superhumps, even though the theta diagrams imply periodicities shorter than the orbital period.

Although we are less confident about the detection of negative superhumps, our result does not mean that SU UMa shows any negative superhumps at all. For example, V344 Lyr and V1504 Cyg exhibited negative superhumps for only 150 d and 260 d against more than 600 d data (Wood et al. 2011; Osaki & Kato 2013). Taking these facts into consideration, our observations are too short to conclude whether SU UMa shows negative superhumps.

As noted in Imada et al. (2012), SU UMa experienced unusual states in the past (Rosenzweig et al. 2000; Kato 2004). According to Rosenzweig et al. (2000), SU UMa hardly showed outbursts for about 3 years, despite the fact that a mean supercycle of SU UMa is $\sim 1$ yr. In addition, SU UMa occasionally entered long quiescence with durations of longer than 50 d (Rosenzweig et al. 2000). Recently, many authors point out that the appearance of negative superhumps suppress an outburst (Ohshima et al. 2012; Osaki & Kato 2013). Based on these ideas, we speculate that such a long quiescence might be associated with negative superhumps. This should be investigated by further quiescent photometry not only for SU UMa, itself, but also for other SU UMa-type dwarf novae.

5. Summary

In this paper, we summarize our results as follows:

1. Quiescence is divided into two types according to the magnitude: faint quiescence and bright quiescence. The former is further divided into two types based on the $g' - R_c$ color. During bright quiescence, the averaged magnitude is $\sim 0.5$ mag brighter than that of faint quiescence.

2. The obtained light curves varied with amplitudes as large as $\sim 1$ mag with irregular and incoherent profiles. Although our period analyses imply periodicities shorter than the orbital period, it is premature to conclude that we detected negative superhumps.

3. During our photometric campaign, SU UMa experienced five normal outbursts, of which three were successfully observed. These outbursts are characteristic of the outside-in type. At the rising phase of the stage-B outburst, hump-like modulations were visible at a period of $\sim 0.048111(354)$ d. The origin of this period remains unknown.

4. Daily-averaged color–color indices of SU UMa revealed two cycles: outburst $\rightarrow$ bright quiescence $\rightarrow$ outburst, and outburst $\rightarrow$ faint quiescence (blue) $\rightarrow$ faint quiescence (red) $\rightarrow$ outburst. This suggests that the thermal limit cycle of the accretion disk for SU UMa is more complicated.

5. The color index in $g' - R_c$ becomes redder $\sim 3$ d prior to an outburst. One possibility is that the inner portion of the accretion disk is filled by gas, which obscures the central white dwarf. We cannot rule out the possibility that the stagnation effect works at the onset of the outburst. The physical mechanism on this reddening should be elucidated in future observations.

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