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ASASSN-19ax: SU UMa-type dwarf nova with a long superhump period and post-superoutburst rebrightenings

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Abstract

We observed ASASSN-19ax during the long outburst in 2021 September–October. The object has been confirmed to be an SU UMa-type dwarf nova with a superhump period of 0.1000–0.1001 d. This object showed two post-superoutburst rebrightenings both in the 2019 and 2021 superoutbursts. These observations have established that ASASSN-19ax belongs to a group of long-period SU UMa-type dwarf novae which show multiple rebrightenings. This phenomenon probably arises from premature quenching of the superoutburst due to the weak 3:1 resonance near the stability border of the resonance, resulting in a considerable amount of disk mass after the superoutburst. We noted that ASASSN-19ax is very similar to QZ Ser, an SU UMa-type dwarf nova with an orbital period of 0.08316 d and an anomalously hot, bright secondary star, in that both objects showed multiple post-superoutburst rebrightenings at least once and that they are bright in quiescence. We expect that the core of the secondary in ASASSN-19ax may be evolved as in QZ Ser.

1 Introduction

ASASSN-19ax is a dwarf nova discovered by the All-Sky Automated Survey for Supernovae (ASAS-SN, Shappee et al. 2014) at g=14.84 on 2019 January 12.[1] The ASAS-SN team described this object as “red star outburst, matches to PS1 G=16.1, previous outburst in CRTS”. Using ASAS-SN Sky Patrol data (Shappee et al. 2014, Kochanek et al. 2017),[2] T.K. noticed that the 2019 January outburst already started on 2018 December 31 (peaking at g=12.9) and that this outburst looked like a superoutburst with a dip and rebrightening (vsnet-alert 22936).[3] Despite the red color, this object was suspected to be an SU UMa-type dwarf nova (vsnet-alert 22936). Although time-resolved observations started on 2019 January 15, the object was already fading and no superhump-like signal was recorded.

[1] <http://www.astronomy.ohio-state.edu/ assassin/transients.html>.
[2] <https://asas-sn.osu.edu/>.
[3] <http://ooruri.kusastro.kyoto-u.ac.jp/mailarchive/vsnet-alert/22936>.

Another outburst was detected by Eddy Muyllaert on 2019 September 5 (originally reported in cvnet-outburst, and cited in vsnet-alert 23543).[4] Although time-resolved observations were initiated, this outburst faded rapidly within 5 d of the initial detection. No periodic modulations were detected and this outburst should have been a normal outburst.

Later on, we used Public Data Release of the Zwicky Transient Facility (Masci et al. 2019) observations[5] and confirmed that the 2019 January outburst was followed by two rebrightenings (figure 1b).

Although multiple rebrightenings are usually seen in WZ Sge-type dwarf novae (Kato 2015), ASASSN-14ho showed four rebrightening despite its long orbital period ($P_{\rm orb}$) of 0.24315(10) d (Gasque et al. 2019). Kato (2020) suggested that ASASSN-14ho is an SU UMa star above the period gap mimicking a WZ Sge-type dwarf nova. There are confirmed instances of long-$P_{\rm orb}$ SU UMa-type dwarf novae with multiple rebrightenings (e.g. ASASSN-18aan: Wakamatsu et al. 2021; QZ Ser: VSNET unpublished, see later in this paper; Mis V1448: N. Kojiguchi et al. in preparation). We therefore considered that ASASSN-19ax should be another long-$P_{\rm orb}$ SU UMa star mimicking a WZ Sge-type dwarf nova.

On 2021 September 10, Eddy Muyllaert detected a bright (m_v=12.8) outburst of this object. Considering the background stated above, we launched a campaign via VSNET Collaboration (Kato et al. 2004) in vsnet-alert 26254.[6] The log of observations (including the 2019 data) is given in table 1.

2 Results and Discussion

The initial observations on 2021 September 16 by S.K. already suggested the presence of superhumps (vsnet-alert 26256).[7] T.V. reported the detection of superhumps with a period of 0.1015(24) d (vsnet-alert 26260).[8] This period was refined by using observations of three observers to 0.10012(2) d (vsnet-alert 26263).[9]

After removing the global trend of the outburst by using locally-weighted polynomial regression (LOWESS, Cleveland 1979), the times of superhumps maxima were determined by the template fitting method as described in Kato et al. (2009). The resultant times of superhump maxima are given in table 2. There appears to be a phase jump between E=59 and E=70. This epoch corresponds to the termination of the initial superoutburst and this phase jump was most likely caused by transition to (traditional) late superhumps[10] (cf. Haefner et al. 1979; Vogt 1983; van der Woerd et al. 1988) arising from the hot spot.

The superhump periods were determined by Phase Dispersion Minimization (PDM; Stellingwerf 1978) method after removing the global trend using LOWESS. The errors were estimated by the methods of Fernie (1989) and Kato et al. (2010). The profiles and periods were almost identical during the superoutburst (period = 0.10013(2) d, figure 2) and the post-superoutburst phase (period = 0.10002(4) d, figure 3) despite a phase jump between them. Superhumps became below the detection limit after BJD 2459485.3. Based on our observations and ASAS-SN data, two post-superoutburst rebrightenings occurred on BJD 2459486 and 2459492.5 (figure 1c). Superhumps disappeared after the first rebrightening. No orbital signal was detected in the ZTF data in quiescence.

These observations have established that ASASSN-19ax belongs to a group of long-$P_{\rm orb}$ SU UMa-type dwarf novae which show multiple rebrightenings. This phenomenon probably arises from premature quenching of the superoutburst due to the weak 3:1 resonance near the stability border of this resonance, resulting in a considerable amount of disk mass after the superoutburst (Kato 2020). The parameters for these objects are summarized in table 3.

The quiescent $M_V = +7.6$ (Gaia Collaboration et al. 2021) is much brighter than $M_V = +12$ expected from the orbital period (Knigge 2006). This implies that the secondary has an evolved core as in QZ Ser, an SU UMa-type dwarf nova with a 2-hour orbital period and an anomalously hot, bright secondary star (Thorstensen et al. 2002). QZ Ser also showed two post-superoutburst rebrightenings after the 2013 March-April superoutburst and one rebrightening in 2020 March-April superoutburst (Kahle 2020, although rebrightenings are not shown).

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[4] <http://ooruri.kusastro.kyoto-u.ac.jp/mailarchive/vsnet-alert/23543>.

[5] The ZTF data can be obtained from IRSA <https://irsa.ipac.caltech.edu/Missions/ztf.html> using the interface <https://irsa.ipac.caltech.edu/docs/program_interface/ztf_api.html> or using a wrapper of the above IRSA API <https://github.com/MickaelRigault/ztfquery>.

[6] <http://ooruri.kusastro.kyoto-u.ac.jp/mailarchive/vsnet-alert/26254>.

[7] <http://ooruri.kusastro.kyoto-u.ac.jp/mailarchive/vsnet-alert/26256>.

[8] <http://ooruri.kusastro.kyoto-u.ac.jp/mailarchive/vsnet-alert/26260>.

[9] <http://ooruri.kusastro.kyoto-u.ac.jp/mailarchive/vsnet-alert/26263>.

[10] Many classical examples of late superhumps in short-$P_{\rm orb}$ systems, however, turned out to be stage C superhumps as described in Kato et al. (2009).

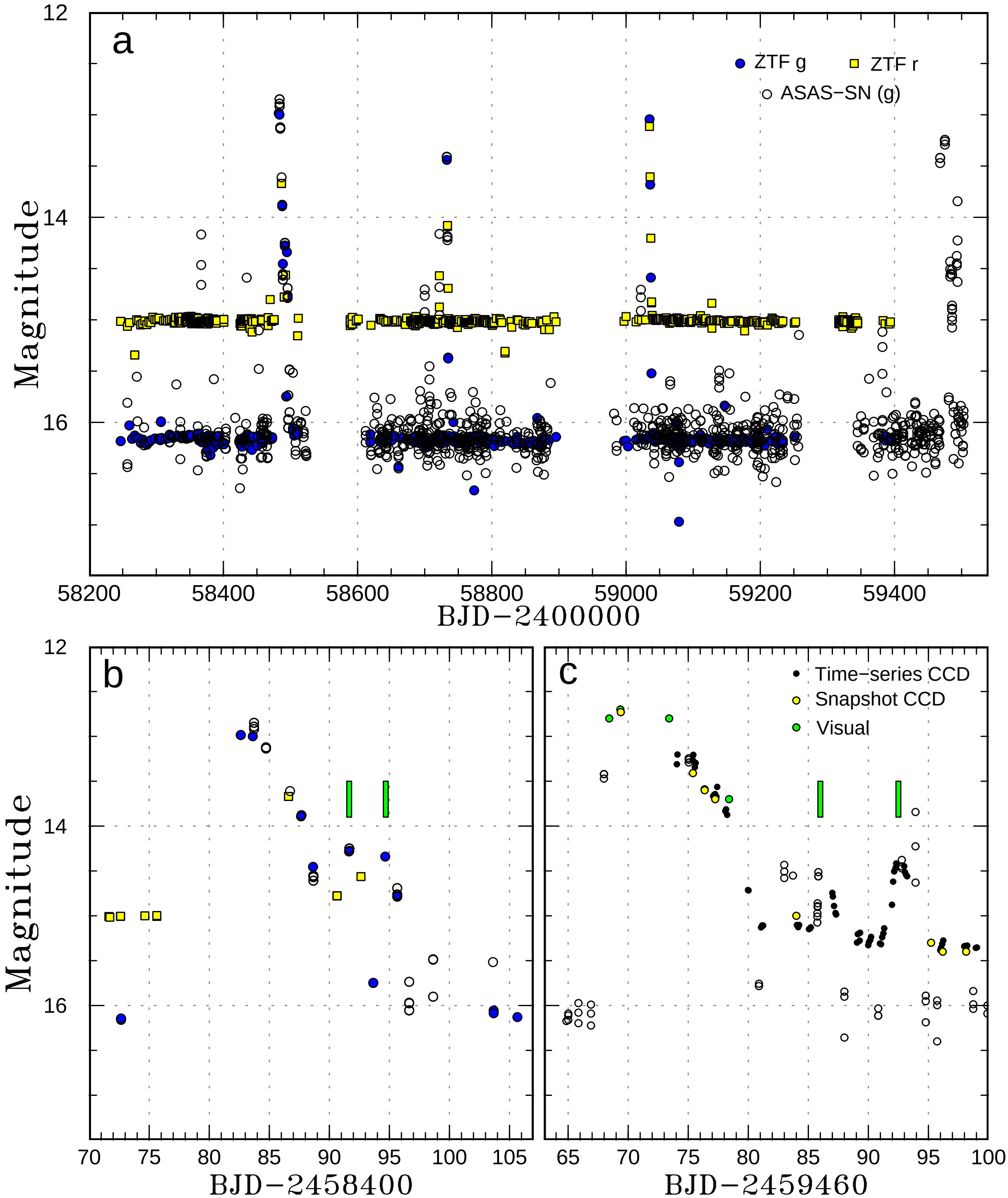

Figure 1: Light curve of ASASSN-19ax. **a**: Long-term light curve based on ASAS-SN and ZTF data. The first and last outbursts were superoutburst and two outbursts between them were normal outbursts. **b**: Superoutburst in 2019 January. Vertical green ticks represent rebrightenings. **c**: Superoutburst in 2021 September. Time-series CCD observations (this work, binned to 0.1 d), snapshot CCD and visual observations from VSNET and VSOLJ were plotted. Vertical green ticks represent rebrightenings.

Table 1: Log of observations of ASASSN-19ax

Start*	End*	mag†	error‡	N§	obs‖	band#
58499.2738	58499.3387	14.262	0.002	61	Van	C
58500.2393	58500.3326	15.002	0.004	87	RPc	V
58501.2928	58501.4191	15.276	0.003	138	Van	C
58732.5664	58732.6240	13.289	0.002	83	Trt	V
58734.1642	58734.2567	14.436	0.002	219	Ioh	C
58736.5648	58736.6851	15.620	0.009	162	DFS	V
58740.1789	58740.3169	15.440	0.006	233	Ioh	C
59474.0042	59474.1054	13.192	0.005	207	Kis	C
59475.3303	59475.6309	13.437	0.004	382	Van	C
59477.0463	59477.3156	13.650	0.003	390	Ioh	C
59477.0582	59477.2289	13.547	0.003	339	Kis	C
59477.3102	59477.4182	13.572	0.006	142	Trt	C
59478.0761	59478.2785	13.845	0.003	389	Ioh	C
59479.9487	59480.0281	14.605	0.007	119	Kis	C
59481.0249	59481.2709	15.118	0.004	383	Ioh	C
59483.9989	59484.2493	14.981	0.004	412	Kis	C
59484.0416	59484.2599	15.161	0.005	222	Ioh	C
59485.0089	59485.2052	15.034	0.004	389	Kis	C
59486.9912	59487.3250	14.920	0.007	264	Ioh	C
59489.0201	59489.3104	15.266	0.007	260	Ioh	C
59489.9769	59490.2410	15.289	0.005	260	Ioh	C
59490.9299	59491.3262	15.260	0.004	666	Ioh	C
59491.9420	59492.3263	14.547	0.007	495	Ioh	C
59492.9612	59493.2458	14.535	0.003	349	Ioh	C
59495.9646	59496.2602	15.331	0.003	503	Ioh	C
59497.9578	59498.2561	15.342	0.002	466	Ioh	C
59498.9098	59499.0653	15.363	0.007	235	Ioh	C
59501.9186	59502.3293	15.294	0.004	331	Ioh	C
59501.9596	59502.2411	1.662	0.001	778	KU1	C
59502.9103	59503.3120	15.315	0.003	281	Ioh	C
59502.9591	59503.1697	1.637	0.001	580	KU1	C
59504.9101	59505.1489	15.388	0.007	147	Ioh	C
59507.9012	59508.0267	15.468	0.006	209	Ioh	C
59510.8743	59511.0001	15.430	0.003	226	Ioh	C
59511.0784	59511.1653	1.572	0.003	188	KU1	C

*JD−2400000.
†Mean magnitude.
‡1σ of the mean magnitude.
§Number of observations.
‖Observer's code: DFS (S. Dufoer), Ioh (H. Itoh), KU1 (Kyoto U., campus obs.), Kis (S. Kiyota), RPc (R. Pickard), Trt (T. Tordai), Van (T. Vanmunster)
#Filter. "C" means unfiltered.

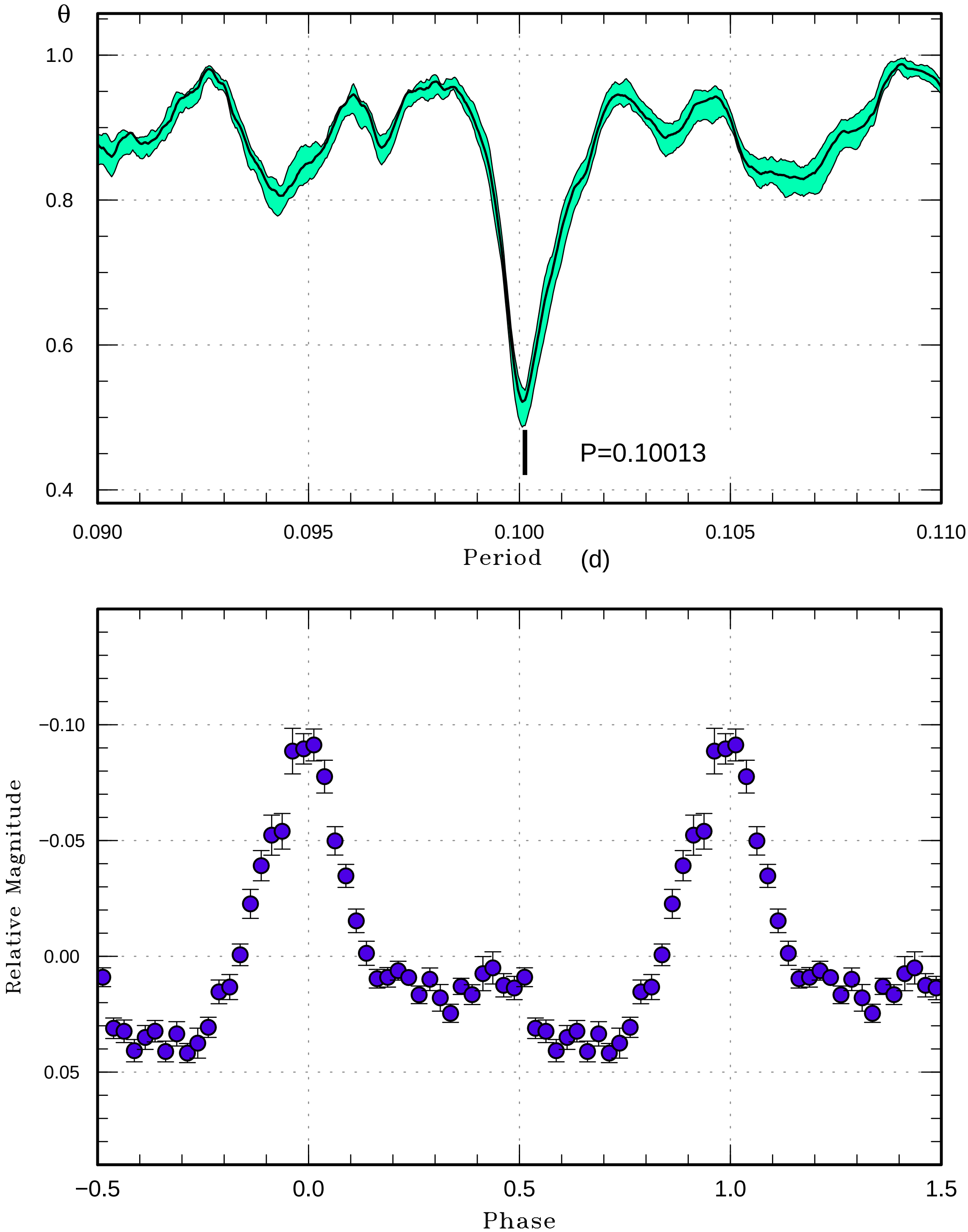

Figure 2: Superhump profile of ASASSN-19ax during the 2021 superoutburst (before BJD 2459481). (Upper): PDM analysis. We analyzed 100 samples which randomly contain 50% of observations, and performed the PDM analysis for these samples. The bootstrap result is shown as a form of 90% confidence intervals in the resultant PDM θ statistics. (Lower): Phase-averaged profile.

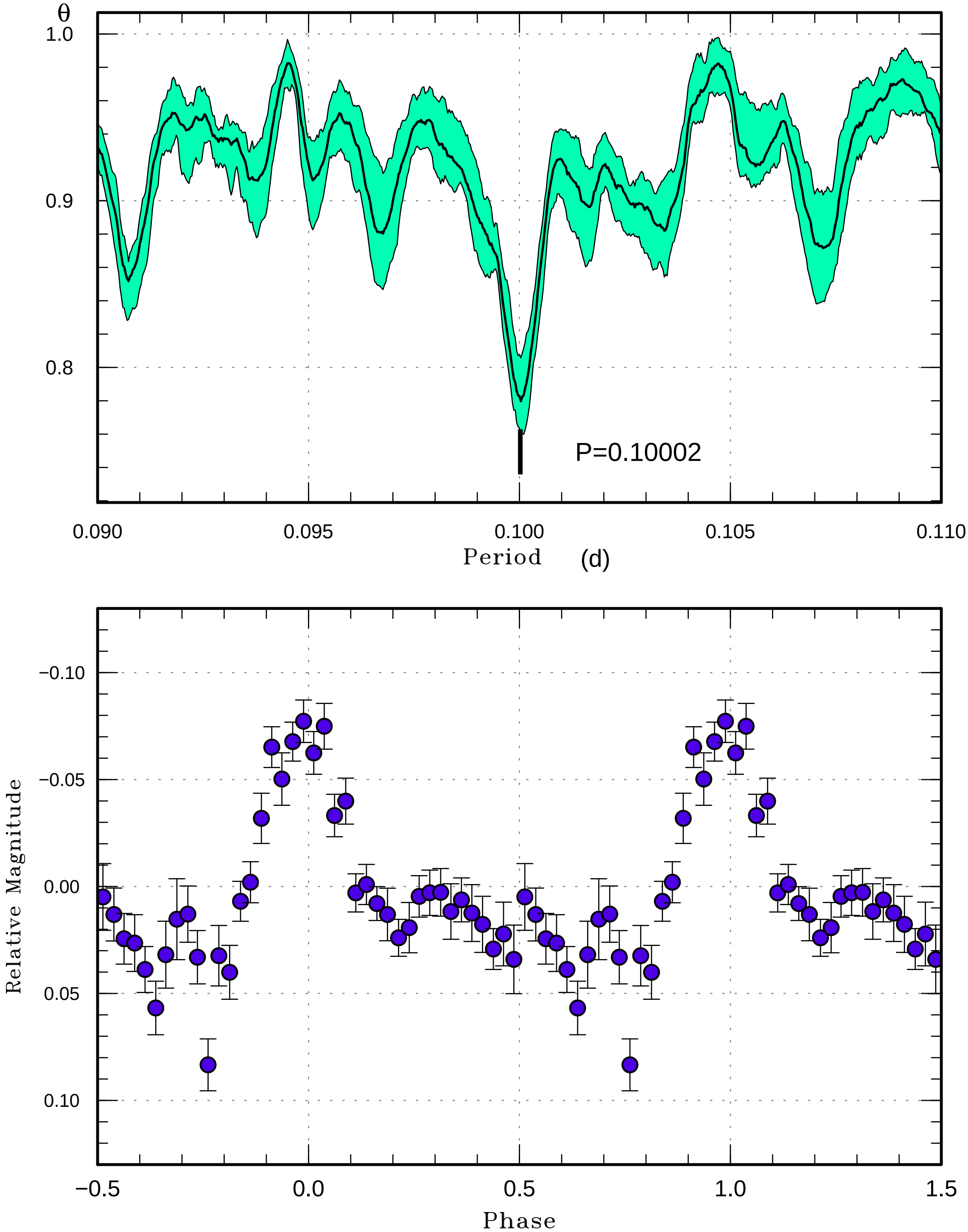

Figure 3: Superhump profile of ASASSN-19ax after the 2021 superoutburst (BJD 2459481–2459486). (Upper): PDM analysis. (Lower): Phase-averaged profile.

Table 2: Superhump maxima of ASASSN-19ax

E	max*	error	$O-C$†	N‡
0	59474.1147	0.0032	0.0105	76
13	59475.4055	0.0004	−0.0027	148
14	59475.5158	0.0052	0.0073	80
15	59475.6048	0.0012	−0.0041	54
30	59477.1103	0.0005	−0.0031	300
31	59477.2088	0.0005	−0.0049	221
32	59477.3122	0.0010	−0.0018	106
33	59477.4115	0.0008	−0.0028	69
40	59478.1158	0.0006	−0.0007	145
41	59478.2101	0.0016	−0.0067	146
59	59480.0031	0.0032	−0.0192	102
70	59481.1384	0.0018	0.0128	118
71	59481.2451	0.0012	0.0191	154
99	59484.0330	0.0019	−0.0015	158
100	59484.1382	0.0009	0.0033	200
101	59484.2342	0.0016	−0.0009	188
109	59485.0387	0.0013	0.0011	130
111	59485.2325	0.0086	−0.0057	34

*BJD−2400000.
†Against max = $2459474.1042 + 0.100306E$.
‡Number of points used to determine the maximum.

Light curves of QZ Ser are given in figure 4 for a comparison. The similarity between ASASSN-19ax and QZ Ser appears to be striking. With the bright (r=15.0) quiescence, detailed spectroscopy of ASASSN-19ax is very promising. There remains, however, a possibility that this r=15.0 object is not the secondary of the ASASSN-19ax binary. The Gaia parallax of this object gives $M_V = +5.3$ for the maximum of ASASSN-19ax, which is not inconsistent with that of a dwarf nova in outburst, and the r=15.0 object is unlikely a background, unrelated star.

Although the 2021 September superoutburst was visually detected early, time-series CCD observations started 5 d later and we probably missed the growing stage of superhumps (stage A superhumps). During the next superoutburst, observations of the early stage will be very important since the period of stage A superhumps is vital for determining the mass ratio (Kato and Osaki 2013), which might be anomalous considering the similarity with QZ Ser.

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Table 3: Long-$P_{\rm orb}$ (suspected) SU UMa-type dwarf novae with multiple rebrightenings

Object	Orbital period (d)	Superhump period (d)*	Number of short rebrightenings	References
QZ Ser	0.083161(1)	0.08557(13)	1–2	Thorstensen et al. (2002), vsnet-alert 15533
OT J002656.6+284933 = CSS101212:002657+284933	–	0.13225(1)	2	Kato et al. (2017)
ASASSN-18aan	0.149454(3)	0.15821(4)	2	Wakamatsu et al. (2021)
Mis V1448	–	0.2275(3)	5	vsnet-alert 24912, N. Kojiguchi et al. in preparation
ASASSN-14ho†	0.24315(10)	–	4	Kato (2020)
OGLE-BLG-DN-0174†	–	0.14474(4)‡	3	Mróz et al. (2015)
OGLE-BLG-DN-0595†	–	0.0972(1)‡	2	Mróz et al. (2015)
ASASSN-19ax	–	0.10013(2)	2	This work

*For stage B superhumps when available.
†Suspected SU UMa star.
‡Requires confirmation (cf. Kato et al. 2017).

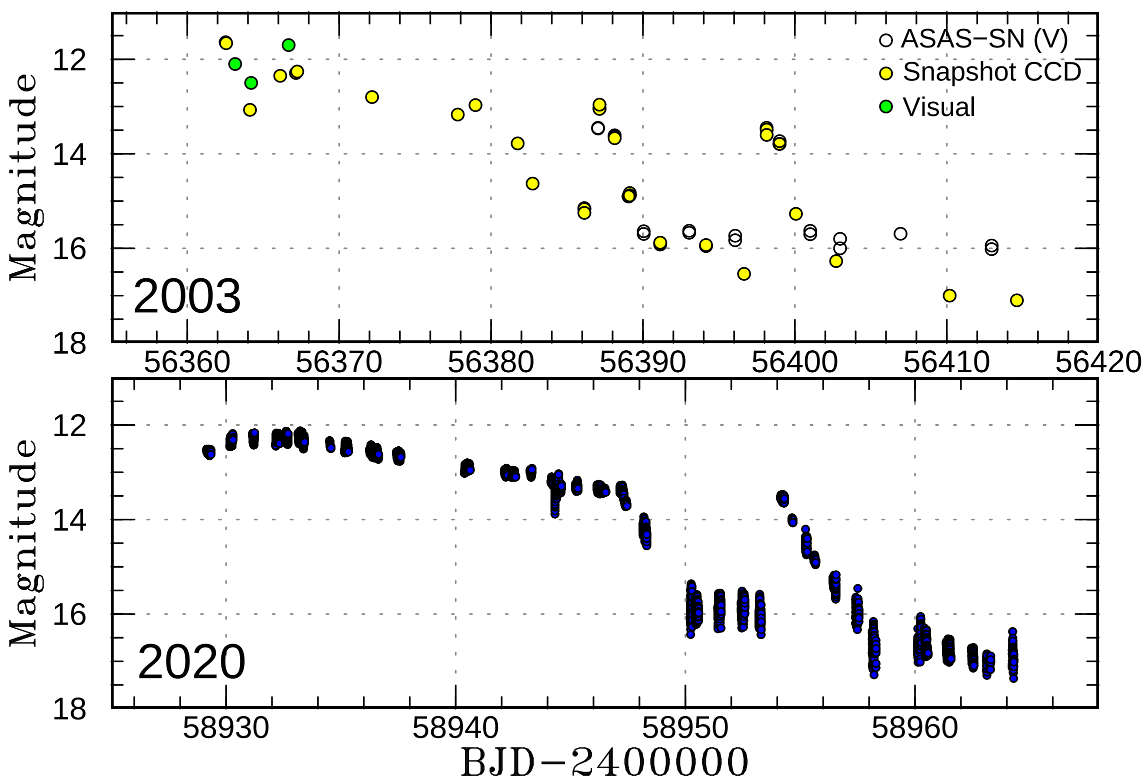

Figure 4: Light curves of superoutbursts of QZ Ser. (Upper): Superoutburst in 2013. ASAS-SN V data, visual and CCD observations reported to VSNET were used. Two post-superoutburst rebrightenings were present. (Lower): Superoutburst in 2020. The data were from VSNET Collaboration. The data were binned to 0.1 d. A post-superoutburst rebrightening is apparent.

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