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Survey of period variations of superhumps in SU UMa-type dwarf novae. X. The tenth year (2017)

Taichi Kato,[1,*] Keisuke Isogai,[1,2] Yasuyuki Wakamatsu,[1] Franz-Josef Hambsch,[3,4,5] Hiroshi Itoh,[6] Tamás Tordai,[7] Tonny Vanmunster,[8] Pavol A. Dubovsky,[9] Igor Kudzej,[9] Tomáš Medulka,[9] Mariko Kimura,[1] Ryuhei Ohnishi,[1] Berto Monard,[10,11] Elena P. Pavlenko,[12] Kirill A. Antonyuk,[12] Nikolaj V. Pit,[12] Oksana I. Antonyuk,[12] Julia V. Babina,[12] Aleksei V. Baklanov,[12] Aleksei A. Sosnovskij,[12] Roger D. Pickard,[13,14] Ian Miller,[15] Yutaka Maeda,[16] Enrique de Miguel,[17,18] Stephen M. Brincat,[19] Domenico Licchelli,[20,21] Lewis M. Cook,[22] Sergey Yu. Shugarov,[23,24] Anna M. Zaostrojnykh,[25] Drahomir Chochol,[24] Polina Golysheva,[23] Natalia Katysheva,[23] Alexandra M. Zubareva,[23,26] Geoff Stone,[27] Kiyoshi Kasai,[28] Peter Starr,[29] Colin Littlefield,[30] Seiichiro Kiyota,[31] Maksim V. Andreev,[32,33] Alexandr V. Sergeev,[32,33] Javier Ruiz,[34,35,36] Gordon Myers,[37] Andrii O. Simon,[38] Volodymyr V. Vasylenko,[38] Francisco Soldán,[39] Yenal Ögmen,[40] Kazuhiro Nakajima,[41] Peter Nelson,[42] Gianluca Masi,[43] Kenneth Menzies,[44] Richard Sabo,[45] Greg Bolt,[46] Shawn Dvorak,[47] Krzysztof Z. Stanek,[48] Joseph V. Shields,[48] Christopher S. Kochanek,[48] Thomas W.-S. Holoien,[48] Benjamin Shappee,[49] José L. Prieto,[50,51] Tadashi Kojima,[52] Hideo Nishimura,[53] Shizuo Kaneko,[54] Shigehisa Fujikawa,[55] Rod Stubbings,[56] Eddy Muyllaert,[57] Gary Poyner,[58] Masayuki Moriyama,[59] Hiroyuki Maehara,[60] Patrick Schmeer,[61] and Denis Denisenko[23]

[1]Department of Astronomy, Kyoto University, Kitashirakawa-Oiwake-cho, Sakyo-ku, Kyoto, Kyoto 606-8502, Japan.
[2]Okayama Observatory, Kyoto University, 3037-5 Honjo, Kamogata-cho, Asakuchi, Okayama 719-0232, Japan
[3]Groupe Européen d'Observations Stellaires (GEOS), 23 Parc de Levesville, 28300 Bailleau l'Evêque, France
[4]Bundesdeutsche Arbeitsgemeinschaft für Veränderliche Sterne (BAV), Munsterdamm 90, 12169 Berlin, Germany
[5]Vereniging Voor Sterrenkunde (VVS), Oude Bleken 12, 2400 Mol, Belgium
[6]Variable Star Observers League in Japan (VSOLJ), 1001-105 Nishiterakata, Hachioji, Tokyo 192-0153, Japan
[7]Polaris Observatory, Hungarian Astronomical Association, Laborc utca 2/c, 1037 Budapest, Hungary
[8]Center for Backyard Astrophysics Belgium, Walhostraat 1A, B-3401 Landen, Belgium
[9]Vihorlat Observatory, Mierova 4, 06601 Humenne, Slovakia
[10]Bronberg Observatory, Center for Backyard Astrophysics Pretoria, PO Box 11426, Tiegerpoort 0056, South Africa

[11]Kleinkaroo Observatory, Center for Backyard Astrophysics Kleinkaroo, Sint Helena 1B, PO Box 281, Calitzdorp 6660, South Africa
[12]Federal State Budget Scientific Institution “Crimean Astrophysical Observatory of RAS”, Nauchny, 298409, Republic of Crimea
[13]The British Astronomical Association, Variable Star Section (BAA VSS), Burlington House, Piccadilly, London W1J 0DU, UK
[14]3 The Birches, Shobdon, Leominster, Herefordshire, HR6 9NG, UK
[15]Furzehill House, Ilston, Swansea, SA2 7LE, UK
[16]12-14 Kaminishiyama-machi, Nagasaki, Nagasaki 850-0006, Japan
[17]Departamento de Ciencias Integradas, Facultad de Ciencias Experimentales, Universidad de Huelva, 21071 Huelva, Spain
[18]Center for Backyard Astrophysics, Observatorio del CIECEM, Parque Dunar, Matalascañas, 21760 Almonte, Huelva, Spain
[19]Flarestar Observatory, San Gwann SGN 3160, Malta
[20]R. P. Feynman Observatory, Gagliano del Capo, 73034, Italy
[21]Center for Backyard Astrophysics – Gagliano del Capo, 73034, Italy
[22]Center for Backyard Astrophysics Concord, 1730 Helix Ct. Concord, CA 94518, USA
[23]Sternberg Astronomical Institute, Lomonosov Moscow State University, Universitetsky Ave., 13, Moscow 119992, Russia
[24]Astronomical Institute of the Slovak Academy of Sciences, 05960 Tatranska Lomnica, Slovakia
[25]Institute of Physics, Kazan Federal University, Ulitsa Kremlevskaya 16a, Kazan 420008, Russia
[26]Institute of Astronomy, Russian Academy of Sciences, Moscow 119017, Russia
[27]American Association of Variable Star Observers, 49 Bay State Rd., Cambridge, MA 02138, USA
[28]Baselstrasse 133D, CH-4132 Muttenz, Switzerland
[29]Warrumbungle Observatory, Tenby, 841 Timor Rd., Coonabarabran, NSW 2357, Australia
[30]Department of Physics, University of Notre Dame, 225 Nieuwland Science Hall, Notre Dame, IN 46556, USA
[31]Variable Star Observers League in Japan, 7-1 Kitahatsutomi, Kamagaya, Chiba 273-0126, Japan
[32]Terskol Branch of Institute of Astronomy, Russian Academy of Sciences, 361605, Peak Terskol, Kabardino-Balkaria Republic, Russia
[33]International Center for Astronomical, Medical and Ecological Research of NASU, Ukraine 27 Akademika Zabolotnoho Str. 03680 Kyiv, Ukraine
[34]Observatorio de Cántabria, Ctra. de Rocamundo s/n, Valderredible, 39220 Cantabria, Spain
[35]Instituto de Física de Cantabria (CSIC-UC), Avenida Los Castros s/n, E-39005 Santander, Cantabria, Spain
[36]Agrupación Astronómica Cántabria, Apartado 573, 39080, Santander, Spain
[37]Center for Backyard Astrophysics San Mateo, 5 Inverness Way, Hillsborough, CA 94010, USA
[38]Astronomy and Space Physics Department, Taras Shevshenko National University of Kyiv, Volodymyrska str. 60, Kyiv, 01601, Ukraine
[39]Observatorio Amanecer de Arrakis, Alcalá de Guadaíra, Petrarca 6, 1A 41006 Seville, Spain
[40]Green Island Observatory, Geçitkale, Magosa, via Mersin, North Cyprus
[41]Variable Star Observers League in Japan, 124 Teradani, Isato-cho, Kumano, Mie 519-4673, Japan
[42]1105 Hazeldean Rd., Ellinbank, VIC 3820, Australia
[43]The Virtual Telescope Project, Via Madonna del Loco 47, 03023 Ceccano (FR), Italy
[44]Center for Backyard Astrophysics (Framingham), 318A Potter Road, Framingham, MA 01701, USA
[45]2336 Trailcrest Dr., Bozeman, MT 59718, USA
[46]Camberwarra Drive, Craigie, Western Australia 6025, Australia
[47]Rolling Hills Observatory, 1643 Nightfall Drive, Clermont, FL 34711, USA
[48]Department of Astronomy, The Ohio State University, Columbia, OH 43210, USA
[49]Carnegie Observatories, 813 Santa Barbara Street, Pasadena, CA 91101, USA
[50]Núcleo de Astronomía de la Facultad de Ingeniería, Universidad Diego Portales, Av. Ejército 441, Santiago, Chile

[51]Department of Astrophysical Sciences, Princeton University, 4 Ivy Lane, Princeton, NJ 08544, USA
[52]Kanbara, Tsumagoi-mura, Agatsuma-gun, Gunma 377-1524, Japan
[53]302-6 Miyawaki, Kakegawa, Shizuoka 436-0086, Japan
[54]14-7 Kami-Yashiki, Kakegawa, Shizuoka 436-0049, Japan
[55]107 Iseki, Oonohara-cho, Kannonji, Kagawa 769-1621, Japan
[56]Tetoora Observatory, 2643 Warragul-Korumburra Road, Tetoora Road, Victoria 3821, Australia
[57]Vereniging Voor Sterrenkunde (VVS), Moffelstraat 13 3370 Boutersem, Belgium
[58]BAA Variable Star Section, 67 Ellerton Road, Kingstanding, Birmingham, B44 0QE, UK
[59]290-383 Ogata-cho, Sasebo, Nagasaki 858-0926, Japan
[60]Subaru Telescope Okayama Branch Office, National Astronomical Observatory of Japan, NINS, 3037-5 Honjo, Kamogata, Asakuchi, Okayama 719-0232, Japan
[61]Bischmisheim, Am Probstbaum 10, 66132 Saarbrücken, Germany

*E-mail: tkato@kusastro.kyoto-u.ac.jp

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Abstract

Continuing the project described by Kato et al. (2009, PASJ, 61, S395), we collected times of superhump maxima for 102 SU UMa-type dwarf novae observed mainly during the 2017 season, and characterized these objects. WZ Sge-type stars identified in this study are PT And, ASASSN-17ei, ASASSN-17el, ASASSN-17es, ASASSN-17fn, ASASSN-17fz, ASASSN-17hw, ASASSN-17kd, ASASSN-17la, PNV J20205397+2508145, and TCP J00332502−3518565. We obtained new mass ratios for seven objects using growing superhumps (stage A). ASASSN-17gf is an EI Psc-type object below the period minimum. CRTS J080941.3+171528 and DDE 51 are objects in the period gap, and both showed a long-lasting phase of stage A superhumps. We also summarize the recent advances in understanding of SU UMa-type and WZ Sge-type dwarf novae.

Key words: accretion, accretion disks — stars: dwarf novae — stars: novae, cataclysmic variables

1 Introduction

This is a continuation of a series of papers, Kato et al. (2009, 2010, 2012a, 2013a, 2014a, 2014b, 2015, 2016b, 2017a), reporting new observations of superhumps in SU UMa-type dwarf novae. [See, e.g., Warner (1995) for SU UMa-type dwarf novae and cataclysmic variables (CVs) in general.]

Upon recommendation from the previous reviewer and the PASJ office we now provide the results in a concise form, presenting the results in the Supporting Information (SI); only the list the objects (table 1), the obtained parameters (table 2), and the references (section 5) are given in the main paper. For the details of the analysis, terminology, and definitions see Kato et al. (2009), and for the initial and current aims of this survey see Kato et al. (2009, 2017a), respectively. For superhump stages, see Kato et al. (2009) and a concise version in e-section 1 in the SI. A short description of the data analysis is given in e-section 2 in the SI. In table 2, P_1 and P_2 represent periods in stages B and C, respectively (P_1 is averaged during the entire course of the observed segment of stage B), and E_1 and E_2 represent the intervals (in cycle numbers) to determine P_1 and P_2, respectively.

2 Data source

The CCD time-series observations were obtained under campaigns led by the VSNET Collaboration (Kato et al. 2004). We also used the public data from the AAVSO International Database.[1]

Outburst detections of many new and known objects relied on the ASAS-SN CV patrol (Davis et al. 2015),[2] the MASTER network (Gorbovskoy et al. 2013), and the Catalina Real-time Transient Survey (CRTS; Drake et al. 2009).[3] Outburst detections were also reported to VSNET, AAVSO,[4] BAAVSS alert,[5] and cvnet-outburst.[6]

1 ⟨http://www.aavso.org/data-download⟩.
2 ⟨http://cv.asassn.astronomy.ohio-state.edu/⟩.
3 ⟨http://nesssi.cacr.caltech.edu/catalina/⟩. For information on the individual Catalina CVs, see ⟨http://nesssi.cacr.caltech.edu/catalina/AllCV.html⟩.
4 ⟨https://www.aavso.org/⟩.
5 ⟨https://groups.yahoo.com/neo/groups/baavss-alert/⟩.
6 ⟨https://groups.yahoo.com/neo/groups/cvnet-outburst/⟩.

Table 1. List of superoutbursts.

Object	Year	Observers or references*	ID†
PT And	2017	DPV, Ioh	
DH Aql	2017	Ioh	
V1047 Aql	2017	SGE, deM, Trt	
NN Cam	2017	DPV	
V391 Cam	2017	Kato et al. (2017a)	
KP Cas	2017	Ioh	
VW CrB	2017	COO, Kis	
V503 Cyg	2017	IMi	
V632 Cyg	2017	deM	
GP CVn	2017	Trt	
GQ CVn	2017	deM, Mdy, COO	
HO Del	2017	BSM	
MN Dra	2017	COO	
OV Dra	2015	Trt	
	2017	DPV, Lis, Ioh, Trt	
V1454 Cyg	2006	Kato et al. (2009)	
BE Oct	2017	HaC	
V521 Peg	2017	Ioh, BSM, RPc	
V368 Per	2017	CRI, Ter, Ioh, Trt, IMi, RPc, DPV	
XY Psc	2017	KU, HaC, Ioh	
V701 Tau	2017	BSM	
V1208 Tau	2017	MZK, CRI, Trt	
TU Tri	2017	Trt, Ioh, RPc, DPV	
SU UMa	2017	DPV	
HS Vir	2007	Njh	
	2017	HaC, DPV, Mdy	
V406 Vir	2017	MLF, MGW, HaC, Nel	
NSV 35	2017	MGW, HaC	
1RXS J161659	2017	deM, IMi	1RXS J161659.5+620014
ASASSN-13ce	2017	Van, Ioh	
ASASSN-13dh	2017	SGE, DPV, IMi, BSM	
ASASSN-14ca	2017	Ter, Trt, Lis, DPV	
ASASSN-14cr	2017	DPV	
ASASSN-14kb	2017	HaC	
ASASSN-14lk	2017	MLF	
ASASSN-15fu	2017	HaC	
ASASSN-15fv	2017	Van	
ASASSN-15qu	2017	MLF, HaC	
ASASSN-17ei	2017	MLF, HaC, SPE	
ASASSN-17el	2017	MLF, HaC	
ASASSN-17eq	2017	Van, Ioh	
ASASSN-17es	2017	HaC, Van, Ioh	
ASASSN-17et	2017	MLF, HaC	
ASASSN-17ew	2017	HaC	
ASASSN-17ex	2017	HaC	
ASASSN-17fh	2017	Van	
ASASSN-17fi	2017	Van	
ASASSN-17fj	2017	HaC	
ASASSN-17fl	2017	HaC	
ASASSN-17fn	2017	Van, Ioh, DPV, Trt, Mdy, Shu, Lic, CRI	
ASASSN-17fo	2017	Mdy, Kis, HaC, Lic, COO, RPc, Ioh, CRI	
ASASSN-17fp	2017	MLF, HaC	
ASASSN-17fz	2017	MLF, HaC, SPE	
ASASSN-17gf	2017	MLF, HaC	
ASASSN-17gh	2017	Ioh, Van	
ASASSN-17gv	2017	MLF, HaC	

Table 1. (Continued)

Object	Year	Observers or references*	ID†
ASASSN-17hm	2017	HaC	
ASASSN-17hw	2017	MLF, HaC, BSM, Ioh, SPE, Shu, Van	
ASASSN-17hy	2017	HaC	
ASASSN-17id	2017	HaC	
ASASSN-17if	2017	HaC	
ASASSN-17ig	2017	GBo, HaC	
ASASSN-17il	2017	Van	
ASASSN-17iv	2017	HaC	
ASASSN-17iw	2017	HaC	
ASASSN-17ix	2017	HaC	
ASASSN-17ji	2017	IMi, Trt, RPc	
ASASSN-17jr	2017	HaC	
ASASSN-17kc	2017	HaC	
ASASSN-17kd	2017	HaC	
ASASSN-17kg	2017	HaC, RPc, Van, Trt	
ASASSN-17kp	2017	Trt, Van, RPc	
ASASSN-17la	2017	COO, Van, DPV, IMi, Trt, NKa, KU	
ASASSN-17lr	2017	IMi	
ASASSN-17me	2017	LCO, CRI	
ASASSN-17np	2017	MLF, HaC	
ASASSN-17nr	2017	HaC	
ASASSN-17of	2017	Van, Ioh, KU, IMi, CRI	
ASASSN-17oo	2017	KU, HaC	
ASASSN-17ou	2017	Shu, KU, HaC, Trt	
ASASSN-17pb	2017	Van, CRI, IMi, KU	
CRTS J044027	2017	HaC, Van	CRTS J044027.1+023301
CRTS J080941	2017	Van, HaC, CRI, Trt	CRTS J080941.3+171528
CRTS J120052	2017	Mdy	CRTS J120052.9−152620
CRTS J122221	2017	Neustroev et al. (2017)	CRTS J122221.6−311524
CRTS J162806	2017	Trt	CRTS J162806.2+065316
CRTS J214934	2017	HaC, Ioh	CRTS J214934.1−121908
CRTS J223235	2017	IMi, Van	CRTS J223235.4+304105
CTCV J1940	2017	HaC	CTCV J1940−4724
DDE 51	2017	Mdy, Trt, RPc, Rui, CRI, IMi	
MASTER J132501	2017	Kai, Lic, deM, Van	MASTER OT J132501.00+431846.1
MASTER J174305	2017	Mdy, Kai, DPV, Lic, Trt	MASTER OT J174305.70+231107.8
MASTER J192757	2017	Van	MASTER OT J192757.03+404042.8
MASTER J200904	2017	KU, deM, Lic	MASTER OT J200904.69+825153.6
MASTER J205110	2017	LCO, Lic, Ioh, KU, Trt	MASTER OT J205110.36+044842.2
MASTER J212624	2017	Shu, DPV, BSM, Trt, RPc, Ioh	MASTER OT J212624.16+253827.2
OT J182142	2017	DPV, Ioh	OT J182142.8+212154
OT J204222	2017	Ioh, LCO, Mas, RPc, Trt, Mdy	OT J204222.3+271211
PNV J202053	2017	deM, CRI, AAVSO, COO, SGE, Lic, Ioh, Trt, Van, OYE, Sol, DPV, Rui, RPc, Kis	PNV J20205397+2508145
SDSS J152857	2017	Van	SDSS J152857.86+034911.7
SDSS 153015	2017b	KU, Trt, CRI	SDSS J153015.04+094946.3
SDSS J204817	2017	BSM, Ioh	SDSS J204817.85−061044.8
TCP J003325	2017	MLF, HaC	TCP J00332502−3518565
TCP J201005	2017	Van, Kai, deM, HaC, SRI, SGE, Trt, DKS, Ioh, Kai, BSM, DPV	TCP J20100517+1303006

*Key to observers. BSM‡: S. Brincat; COO: L. Cook; CRI: Crimean Astrophys. Obs.; deM: E. de Miguel; DKS‡: S. Dvorak; DPV: P. Dubovsky; GBo: G. Bolt; HaC: F.-J. Hambsch, remote obs. in Chile; IMi‡: I. Miller; Ioh: H. Itoh; KU: Kyoto U. (campus obs.); Kai: K. Kasai; Kis: S. Kiyota; LCO: C. Littlefield; Lic: D. Licchelli; Lis: Lisnyky Obs.; NGW‡: G. Myers; MLF: B. Monard; MZK‡: K. Menzies; Mas: G. Masi; Mdy: Y. Maeda; NKa: N. Katysheva and S. Shugarov; Nel: P. Nelson; Njh: K. Nakajima; OYE‡: Y. Ögmen; RPc‡: R. Pickard; Rui: J. Ruiz; SGE‡: G. Stone; SPE‡: P. Starr; SRI‡: R. Sabo; Shu: S. Shugarov team; Sol: F. Soldán; Ter: Terskol Obs.; Trt: T. Tordai; , Van: T. Vanmunster; AAVSO: AAVSO database.

†Original identifications, discoverers, or data source.

‡Inclusive of observations from the AAVSO database.

Table 2. Superhump periods and period derivatives.

Object	Year	P_1 (d)	Error	E_1*		$P_{\rm dot}$†	Error†	P_2 (d)	Error	E_2*		$P_{\rm orb}$ (d)‡	Q§
V1047 Aql	2017	0.073914	0.000098	0	19	—	—	—	—	—	—	—	C
V391 Cam	2017	—	—	—	—	—	—	0.056728	0.000012	209	263	0.05620	C
KP Cas	2017	—	—	—	—	—	—	0.085143	0.000242	0	13	—	C
VW CrB	2017	0.071985	0.000528	0	11	—	—	—	—	—	—	—	C
V632 Cyg	2017	0.0655	0.0003	0	2	—	—	—	—	—	—	—	C
OV Dra	2017	0.060398	0.000033	0	98	14.5	2.4	0.060032	0.000057	94	150	0.058736	B
GQ CVn	2017	0.089476	0.000091	0	37	—	—	—	—	—	—	—	C
BE Oct	2017	0.077115	0.000132	0	40	—	—	—	—	—	—	—	C
V521 Peg	2017	0.061646	0.000065	0	29	—	—	—	—	—	—	—	C
V368 Per	2017	0.079224	0.000028	0	41	—	—	0.078602	0.000166	63	79	—	B
XY Psc	2017	0.060675	0.000045	0	83	13.7	2.3	0.060230	0.000053	82	99	—	C
V701 Tau	2017	0.069026	0.000037	0	31	—	—	—	—	—	—	—	C
V1208 Tau	2017	0.0698	0.0040	0	3	—	—	—	—	—	—	0.0681	C
TU Tri	2017	0.076246	0.000080	0	20	—	—	—	—	—	—	—	C
SU UMa	2017b	0.078924	0.000123	0	64	—	—	—	—	—	—	0.07635	C
HS Vir	2017	0.080313	0.000063	0	103	3.7	4.9	—	—	—	—	0.0769	CG
V406 Vir	2017	0.056960	0.000016	0	88	8.1	1.5	—	—	—	—	0.05592	B
1RXS J161659	2017	0.071028	0.000032	0	70	−10.6	3.3	—	—	—	—	—	CG
ASASSN-13dh	2017	—	—	—	—	—	—	0.091322	0.000056	38	100	—	B
ASASSN-14ca	2017	0.067036	0.000014	0	45	−4.7	3.0	—	—	—	—	—	C
ASASSN-14cr	2017	—	—	—	—	—	—	0.068698	0.000055	0	45	—	C
ASASSN-14kb	2017	0.070420	0.000030	0	86	3.0	3.9	—	—	—	—	0.068106	CG
ASASSN-14lk	2017	—	—	—	—	—	—	0.061054	0.000094	0	34	—	C
ASASSN-15fu	2017	0.074592	0.000071	0	28	—	—	—	—	—	—	—	CG
ASASSN-15fv	2017	0.0682	0.0040	0	1	—	—	—	—	—	—	—	C
ASASSN-15qu	2017	0.080449	0.000038	0	78	−7.5	3.8	—	—	—	—	—	CG
ASASSN-17ei	2017	0.057257	0.000011	34	247	3.4	0.4	—	—	—	—	0.05646	BE
ASASSN-17el	2017	0.055183	0.000013	48	213	5.1	0.3	0.054911	0.000184	230	271	0.05434	BE
ASASSN-17eq	2017	0.072197	0.000069	0	28	—	—	—	—	—	—	—	C
ASASSN-17es	2017	0.057858	0.000023	33	105	0.6	4.4	—	—	—	—	0.05719	BE
ASASSN-17et	2017	—	—	—	—	—	—	0.095636	0.000060	0	63	—	C
ASASSN-17ew	2017	—	—	—	—	—	—	0.078497	0.000027	0	65	—	C
ASASSN-17ex	2017	—	—	—	—	—	—	0.068306	0.000096	0	31	—	C
ASASSN-17fh	2017	0.064	0.001	0	1	—	—	—	—	—	—	—	C
ASASSN-17fi	2017	0.058833	0.000011	0	52	—	—	—	—	—	—	—	C
ASASSN-17fj	2017	0.066266	0.000021	0	77	8.4	2.3	0.065950	0.000044	75	135	—	B
ASASSN-17fl	2017	0.062632	0.000123	0	18	—	—	—	—	—	—	—	C
ASASSN-17fn	2017	0.061584	0.000014	37	169	−2.8	1.4	—	—	—	—	0.06096	BE
ASASSN-17fo	2017	0.063240	0.000028	8	80	7.3	3.8	—	—	—	—	0.061548	B
ASASSN-17fz	2017	0.054404	0.000025	41	152	7.0	2.0	—	—	—	—	—	B
ASASSN-17gf	2017	0.052551	0.000010	31	129	5.2	1.0	—	—	—	—	—	B
ASASSN-17gh	2017	0.061394	0.000348	0	9	—	—	—	—	—	—	—	C
ASASSN-17gv	2017	0.060897	0.000039	0	88	—	—	—	—	—	—	—	CG
ASASSN-17hm	2017	0.088586	0.000073	0	37	—	—	0.088140	0.000059	34	59	—	C
ASASSN-17hw	2017	0.059717	0.000013	29	218	0.3	0.9	—	—	—	—	0.05886	BE
ASASSN-17hy	2017	0.071475	0.000048	0	72	16.3	4.3	—	—	—	—	—	C
ASASSN-17id	2017	0.078613	0.000074	0	39	—	—	—	—	—	—	—	C2
ASASSN-17if	2017	0.058827	0.000031	0	154	8.2	0.8	0.058568	0.000041	153	223	—	B
ASASSN-17ig	2017	0.094947	0.000084	0	25	—	—	0.094393	0.000024	25	96	—	C
ASASSN-17iv	2017	—	—	—	—	—	—	0.070237	0.000044	15	87	—	C
ASASSN-17iw	2017	0.055906	0.000047	0	90	11.3	5.9	—	—	—	—	—	C
ASASSN-17ix	2017	0.062449	0.000048	0	82	18.2	4.0	—	—	—	—	—	C
ASASSN-17ji	2017	0.0589	0.0001	0	18	—	—	—	—	—	—	—	C
ASASSN-17jr	2017	0.061706	0.000038	0	98	8.0	3.0	—	—	—	—	—	C
ASASSN-17kc	2017	0.063764	0.000028	0	81	12.8	1.4	0.063320	0.000024	80	160	—	B

Table 2. (Continued)

Object	Year	P_1 (d)	Error	E_1*		P_{dot}†	Error†	P_2 (d)	Error	E_2*		P_{orb} (d)‡	Q§
ASASSN-17kd	2017	0.060919	0.000016	33	213	2.7	0.8	—	—	—	—	—	B
ASASSN-17kg	2017	0.057620	0.000017	36	228	5.4	0.5	0.057427	0.000025	242	297	—	A
ASASSN-17kp	2017	0.057957	0.000030	0	51	9.3	5.7	—	—	—	—	—	C
ASASSN-17la	2017	0.061571	0.000021	27	175	7.9	0.5	—	—	—	—	0.06039	BE
ASASSN-17lr	2017	0.058635	0.000057	0	102	−8.8	3.2	—	—	—	—	—	CG
ASASSN-17me	2017	0.0614	0.0004	0	1	—	—	—	—	—	—	—	C
ASASSN-17np	2017	0.089227	0.000047	0	26	—	—	0.088730	0.000032	25	82	—	C
ASASSN-17nr	2017	0.056376	0.000027	0	107	5.8	1.6	—	—	—	—	—	CU
ASASSN-17of	2017	0.064175	0.000067	0	74	—	—	0.063567	0.000030	74	109	—	C
ASASSN-17oo	2017	0.06781	0.00005	—	—	—	—	—	—	—	—	—	C2
ASASSN-17ou	2017	0.057128	0.000045	0	70	—	—	—	—	—	—	—	C
ASASSN-17pb	2017	0.076092	0.000049	47	101	−1.0	8.6	—	—	—	—	—	C
CRTS J044027	2017	—	—	—	—	—	—	0.064361	0.000034	49	97	—	C
CRTS J080941	2017	0.100467	0.000122	20	62	—	—	—	—	—	—	—	B
CRTS J214934	2017	0.071482	0.000005	0	65	—	—	0.071222	0.000041	64	107	—	C
CRTS J223235	2017	0.062994	0.000136	0	32	—	—	—	—	—	—	—	C
CTCV J1940	2017	0.076668	0.000027	0	79	−3.7	3.2	—	—	—	—	—	CU
DDE 51	2017	0.100277	0.000020	49	108	−0.5	2.1	—	—	—	—	—	B
MASTER J174305	2017	0.069949	0.000079	0	14	—	—	0.069425	0.000074	27	44	—	C
MASTER J192757	2017	0.08161	0.00005	0	12	—	—	—	—	—	—	—	C
MASTER J200904	2017	0.073646	0.000115	0	20	—	—	—	—	—	—	—	C
MASTER J205110	2017	0.080710	0.000044	0	59	7.6	4.7	—	—	—	—	—	C
MASTER J212624	2017	0.090888	0.000074	43	75	—	—	—	—	—	—	—	B
NSV 35	2017	0.081034	0.000039	0	112	−1.1	2.4	—	—	—	—	—	BG
OT J182142	2017	0.082140	0.000095	0	40	—	—	—	—	—	—	—	C2
OT J204222	2017	0.056152	0.000045	65	167	−1.1	6.6	—	—	—	—	—	C
PNV J202053	2017	0.057392	0.000010	53	250	4.3	0.4	0.056443	0.000153	246	263	0.056509	AE
SDSS J152857	2017	0.06319	0.00024	0	3	—	—	—	—	—	—	—	C
SDSS J153015	2017b	0.075310	0.000134	0	32	—	—	—	—	—	—	—	C
TCP J003325	2017	0.055222	0.000019	91	256	4.6	0.3	—	—	—	—	0.05485	BE
TCP J201005	2017	0.081030	0.000046	0	44	—	—	—	—	—	—	—	B2

*Interval used for calculating the period.

†In units of 10^{-5}.

‡References: V391 Cam (Kapusta & Thorstensen 2006); V1208 Tau (Patterson et al. 2005); SU UMa (Thorstensen et al. 1986); HS Vir (Mennickent et al. 1999); V406 Vir (Zharikov et al. 2006); ASASSN-14kb (Wyrzykowski et al. 2014); PT And, OV Dra, ASASSN-17ei, ASASSN-17el, ASASSN-17es, ASASSN-17fn, ASASSN-17fo, ASASSN-17hw, ASASSN-17la, PNV J202053, and TCP J003325 (this work).

§Data quality and comments. A: excellent; B: partial coverage or slightly low quality; C: insufficient coverage or observations with large scatter; G: P_{dot} denotes global P_{dot}; M: observational gap in middle stage; U: uncertainty in alias selection; 2: late-stage coverage, the listed period may refer to P_2; E: P_{orb} refers to the period of early superhumps.

3 Major findings for objects in this paper

In this section we list the major findings of this paper.

(1) Suspected WZ Sge-type dwarf novae XY Psc and V406 Vir underwent long-awaited superoutbursts, but neither of them showed WZ Sge-type characteristics.

(2) ASASSN-17fo is a deeply eclipsing SU UMa-type dwarf nova.

(3) ASASSN-17gf is an EI Psc-type object below the period minimum.

(4) ASASSN-17kg showed a dip before the termination of the superoutburst.

(5) ASASSN-171a is a WZ Sge-type dwarf nova with an intermediate mass ratio [0.084(5)] and a medium long orbital period [0.06039(3) d].

(6) CRTS J080941 and DDE 51 are in the period gap and had a long-lasting stage A.

(7) MASTER J212624 is a long-period system with a long-lasting stage A.

(8) WZ Sge-type stars identified in this study are PT And, ASASSN-17ei, ASASSN-17el, ASASSN-17es, ASASSN-17fn, ASASSN-17fz, ASASSN-17hw, ASASSN-17kd, ASASSN-17la, PNV J202053, and TCP J003325.

(9) New mass ratios from stage A superhumps, using Kato and Osaki (2013), are ASASSN-17ei: 0.074(3);

ASASSN-17el: 0.071(3); ASASSN-17es: 0.095(9); ASASSN-17fn: 0.097(1); ASASSN-17hw: 0.078(1); CRTS J122221: 0.032(2); PNV J202053: 0.090(3).

4 Summary of recent progress in understanding SU UMa-type dwarf novae

In this section we provide brief descriptions of recent progress in understanding SU UMa-type dwarf novae based on this series of papers and other published papers, as requested by the reviewer.

4.1 SU UMa-type dwarf novae and superhump stages

For SU UMa-type dwarf novae in general, we have verified that the relation between the period derivative ($P_{\rm dot}$) for stage B versus the orbital period ($P_{\rm orb}$) that we found in Kato et al. (2009) essentially applies to most ordinary superoutbursts. The refined relation was shown in Kato et al. (2016b, 2017a)—we consider Kato et al. (2017a) to be the final regular summary of the statistics. Stages A, B, and C are now well established and used in many publications by various authors, for example, Katysheva, Chochol, and Shugarova (2014), Bąkowska et al. (2014, 2017), Sklyanov et al. (2016, 2018), Neustroev et al. (2017, 2018), Littlefield et al. (2018), Pala et al. (2018, 2019), Pavlenko et al. (2019), McAllister et al. (2019), and Court et al. (2019)— the latter work also illustrates the difficulty in determining superhump times in a deeply eclipsing system. The rapid growth in the number of papers referring to our superhump stages indicates that this concept and application are now widely accepted in this field.

4.2 SU UMa-type / WZ Sge-type relation and period bouncers

The SU UMa-type / WZ Sge-type relation and the nature of period bouncers will be one of the most intriguing subjects for many readers. We have already give a conclusion to this subject as a review (Kato 2015). The distinction between SU UMa-type and WZ Sge-type dwarf novae is the manifestation of the 2 : 1 resonance in the latter, and this classification is now widely accepted (such as in AAVSO VSX[7]). After the release of Kato (2015), there have been an increasing number of WZ Sge-type dwarf novae, mainly thanks to the ASAS-SN survey. The major advance since then has been the increase in examples of type-E outbursts. Objects with type-E outbursts have an initial superoutburst corresponding to the 2 : 1 resonance (high-inclination systems show early superhumps) and a second superoutburst showing the development of ordinary superhumps. They are considered to be the best candidates for the still elusive population of period bouncers. The papers dealing with type-E outbursts are Kimura et al. (2016b) [ASASSN-15jd], Kimura et al. (2018) [ASASSN-16dt and ASASSN-16hg], and Isogai et al. (2019) [NSV 1440, AM CVn star]. Among these, ASASSN-15jd and ASASSN-16hg showed a transitional feature between a single superoutburst and the type-E outburst. These observations suggest that type-E outbursts can be understood as a smooth extension of WZ Sge-type dwarf novae toward a lower mass ratio (i.e., period bouncers). The examples are still increasing and the results are pending publication.

4.3 Systems near the stability border of the 3 : 1 resonance

The major recent advance in SU UMa-type dwarf novae is around the stability borderline of the 3 : 1 resonance. When Kato et al. (2009) was published, it was a mystery why some long-$P_{\rm orb}$ systems show a strong decrease of the superhump periods [cf. MN Dra and UV Gem; see subsection 4.10 in Kato et al. (2009)]. An idea to solve this issue required five years to appear and Kato et al. (2014b) gave a working hypothesis that the 3 : 1 resonance slowly grows in systems near the stability border of the 3 : 1 resonance. This idea has been reinforced by subsequent observations (Kato et al. 2016c). Kato et al. (2016b, 2017a) increased the number of candidate systems showing this feature. Some of these objects are known to show post-superoutburst rebrightenings, which had usually been considered to be a feature unique to WZ Sge-type dwarf novae (cf. Kato 2015). With the increasing number of long-$P_{\rm orb}$ objects showing rebrightenings [V1006 Cyg: Kato et al. (2016c); ASASSN-14ho: Kato (2020)], it is now considered that the weak 3 : 1 resonance could cause decoupling of the tidal and thermal instabilities, leading to premature quenching of the superoutburst. This idea was originally proposed for extremely low-mass-ratio systems such as WZ Sge-type dwarf novae (Hellier 2001). Recent findings suggest that the same mechanism could work in systems near the stability border of the 3 : 1 resonance, and that such systems can mimic WZ Sge-type outbursts. A long precursor followed by a dip and an ordinary superoutburst in CS Ind (Kato et al. 2019b) also strengthens this interpretation. Theoretical support is still lacking, and further advance is to be expected in this regime.

4.4 SU UMa-type dwarf nova showing standstills

Currently there is only one known SU UMa-type dwarf nova (NY Ser) which showed standstills in 2018 (Kato et al. 2019a). This is a single known bona fide hybrid

[7] ⟨https://www.aavso.org/vsx/⟩.

SU UMa + Z Cam-type dwarf nova. It was shown that superoutbursts arose from standstills in NY Ser, and the disk should grow in radius to reach the 3 : 1 resonance during standstills.

5 List of references

The references cited in the SI are Alksnis and Zharova (2000), Antipin (1996), Antipin and Pavlenko (2002), Augusteijn et al. (2010), Aviles et al. (2010), Balanutsa et al. (2012, 2013, 2014a, 2014b, 2017), Boyd et al. (2010), Cannon (1925), Cartier et al. (2017), Cleveland (1979), Davis et al. (2014), Denisenko (2017), Denisenko et al. (2013), Dillon et al. (2008), Drake et al. (2014), Erastova (1973), Fernie (1989), Green et al. (1982, 1986), Grubissich and Rosino (1958), Harvey et al. (1995), Henden, Munari, and Sumner (2001), Hoffmeister (1949a, 1949b, 1957a, 1957b, 1963, 1964, 1967), Imada et al. (2017), Kato (2015), Kato et al. (1995, 1998, 2001b, 2009, 2010, 2012a, 2013a, 2013b, 2014a, 2014b, 2015, 2016a, 2016b, 2016c, 2017a, 2017b), Kato, Ishioka, and Uemura (2002), Kato, Maehara, and Uemura (2012b), Kato, Sekine, and Hirata (2001a), Khruslov (2005), Kimura et al. (2016a), Kinnunen and Skiff (2000), Littlefield et al. (2013), Liu et al. (1999), Liu and Hu (2000), Luyten (1938), Marsh, Parsons, and Dhillon (2017), Mason and Howell (2003), Mennickent, Matsumoto, and Arenas (1999), Motch et al. (1996), Mróz et al. (2015), Nakata et al. (2013), Namekata et al. (2017), Neustroev et al. (2017), Nogami et al. (2003), Nogami and Kato (1995), Novák (1997), Osaki and Kato (2013a, 2013b), Ohnishi et al. (2019), Ohshima et al. (2012), Osminkin (1985), Patterson et al. (2003, 2005), Patterson, Thorstensen, and Knigge (2008), Pavlenko et al. (2012), Pojmański (2002), Prieto et al. (2014), Richter (1969), Ringwald (1993), Rodríguez-Gil et al. (2005), Romano (1978), Rosino and Pigatto (1972a, 1972b), Sharov (1991), Sharov, Goranskij and Samus (1992), Sharov and Alksnis (1989), Shears and Boyd (2007), Shears et al. (2008), Sheets et al. (2007), Shumkov et al. (2017), Stanek et al. (2013), Stellingwerf (1978), Szkody et al. (2003, 2006, 2009), Thorstensen et al. (2002), Uemura et al. (2002), Waagen (2017), Wakamatsu et al. (2017), Wenzel (1989), Williams et al. (2010), Wood et al. (2011), Woudt et al. (2012), Woudt and Warner (2010), Wyrzykowski et al. (2014), Zemko, Kato, and Shugarov (2013), Zharikov et al. (2006), Zheng et al. (2010), and Zloczewski (2004).

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Supplementary data

The following supplementary data are available at PASJ online.

Observation results of superhump maxima for 102 SU UMa-type dwarf novae (e-figures 1–101, e-tables 1–100).

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