No.121 Jul. 2023

Variable Star Bulletin

SDSS J183131.63+420220.2: AM CVn star showing ER UMa-type behavior and long standstill

Taichi Kato[1]

tkato@kusastro.kyoto-u.ac.jp

[1] Department of Astronomy, Kyoto University, Sakyo-ku, Kyoto 606-8502, Japan

Received 2023 Jul. 14

Abstract

SDSS J183131.63+420220.2 is an AM CVn-type cataclysmic variable. Using Asteroid Terrestrial-impact Last Alert System (ATLAS) and Zwicky Transient Facility (ZTF) data, I found that this object is actually a helium dwarf nova, which experienced a long (∼6 yr) standstill (2017 to 2022). The object is currently (in 2023) in ER UMa-type state with supercycles of 20–30 d and large duty cycles exceeding 0.5. This object is the second known star among AM CVn stars having characteristics of ER UMa and Z Cam types. The long duration of the standstill phase is outstanding among helium dwarf novae. These observations indicate that the accretion disk in SDSS J183131.63+420220.2 is very close to thermal stability. I detected a period of 0.01602343(1) d in the ZTF data, which can be the orbital one. Combined with the case of MGAB-V240, the limit of thermal stability of the disks in AM CVn stars appears to be located around the orbital period of 0.0158–0.0160 d.

SDSS J183131.63+420220.2 was selected as a white dwarf candidate from Sloan Digital Sky Survey (SDSS) colors and was classified as a cataclysmic variable (CV) by Girven et al. (2011). This object was spectroscopically classified as a DB white dwarf by Kleinman et al. (2013). The variability of this object was detected by Asteroid Terrestrial-impact Last Alert System (ATLAS: Tonry et al. 2018) and was listed as ATO J277.8818+42.0389 with a classification of "irregular" (Heinze et al. 2018).[1] The variation was also detected by Zwicky Transient Facility (ZTF: Masci et al. 2019) and was given a name of ZTF J183131.63+420220.1 (Ofek et al. 2020). Most recently, Gaia Collaboration et al. (2022) listed this object as a CV (Gaia DR3 2111270034246759424).

Inight et al. (2023) studied this object and classified it as an AM CVn star with a helium-dominated absorption line spectrum and showing occasional "drop-outs" (fading) in the ZTF and Gaia light curves. Inight et al. (2023) described that the drop-outs in the Gaia and ZTF light curves are unusual for this type (i.e. AM CVn) of system.

Using ZTF and ATLAS data, I found that this object currently (in 2023) shows ER UMa-type (subclass of SU UMa stars; see e.g. Kato et al. 1999) variations (vsnet-alert 27896). The long-term light curves are shown in figures 1 and 2. The enlarged 2023 light curve is shown in figure 3. Long outbursts (superoutbursts) were intervened by short fading episodes. Short outbursts are also also evident around BJD 2460131 and 2460133. The recurrence times of long outbursts varied between 20 and 30 d. The duty cycles of long outbursts were ∼0.5 or even larger. The current light curve is very similar to the AM CVn star MGAB-V240 particularly in 2021 to 2022 (Kato 2023). It is also similar to the hydrogen-rich ER UMa star RZ LMi when it showed standstills (Kato et al. 2016). MGAB-V240 was the second AM CVn-type object showing true standstills after CR Boo (Kato et al. 2023). SDSS J183131.63+420220.2 has become the third known such an object and is notable in that it showed a very long standstill lasting almost 6 yr, while the other two objects showed relatively short ones. The suggested type is SU UMa(ER UMa)+Z Cam+AM CVn, the same as for MGAB-V240.

The discussion in MGAB-V240 (Kato 2023) also applies to SDSS J183131.63+420220.2. The accretion disk in this object should be very close to the thermal stability. Using the ZTF data during the standstill, I detected

[1]Although I used this as the primary name in vsnet-alert 27896 (<http://ooruri.kusastro.kyoto-u.ac.jp/mailarchive/vsnet-alert/27896>), which first described variability, I here use the SDSS name knowing that the CV nature had already been recognized.

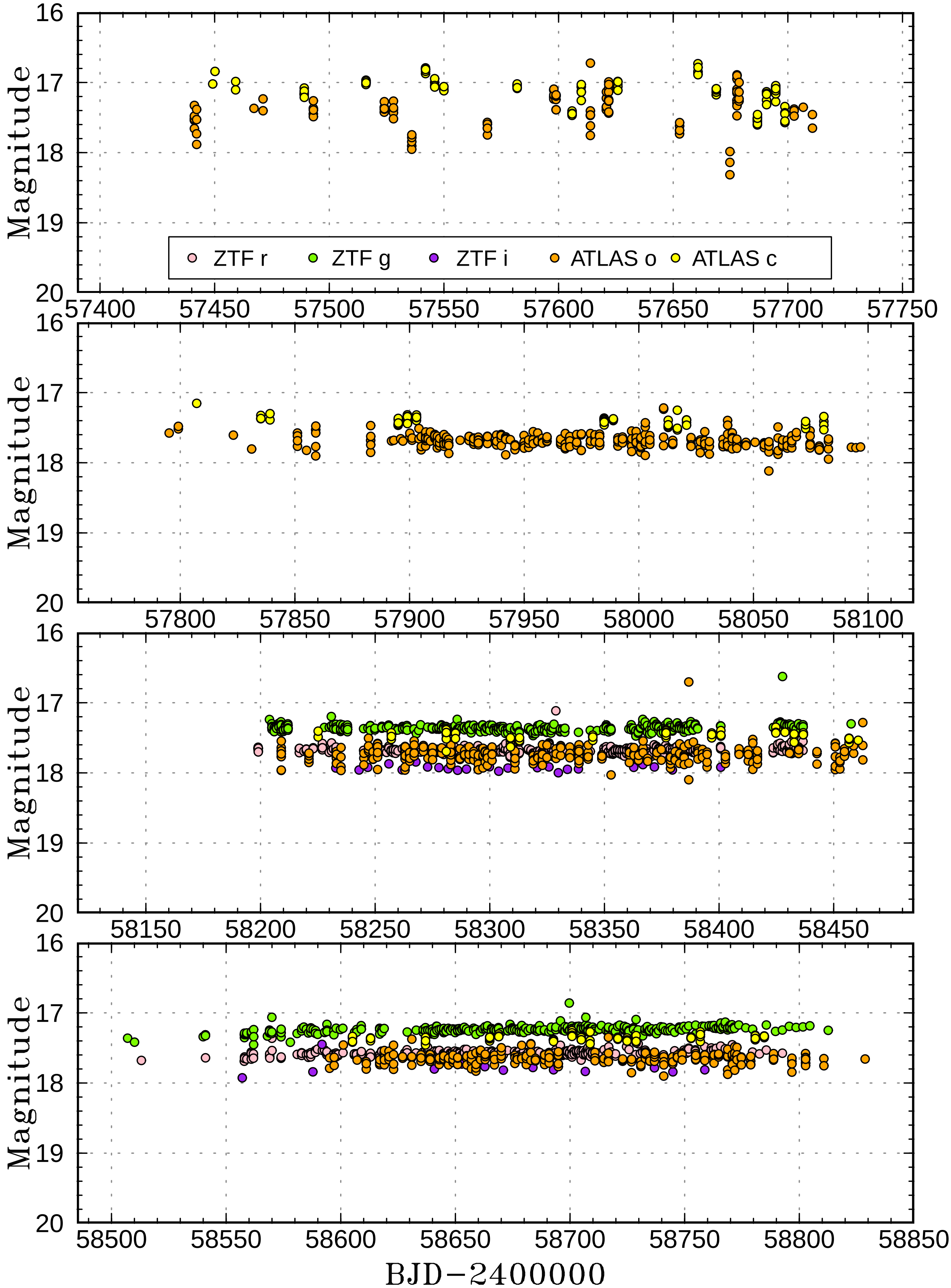

Figure 1: Light curve of SDSS J183131.63+420220.2 in 2016–2019. The object was mostly in nearly constant brightness in 2017–2019. Larger-amplitude variations were present in 2016, as was also evident in Gaia observations shown in Inight et al. (2023).

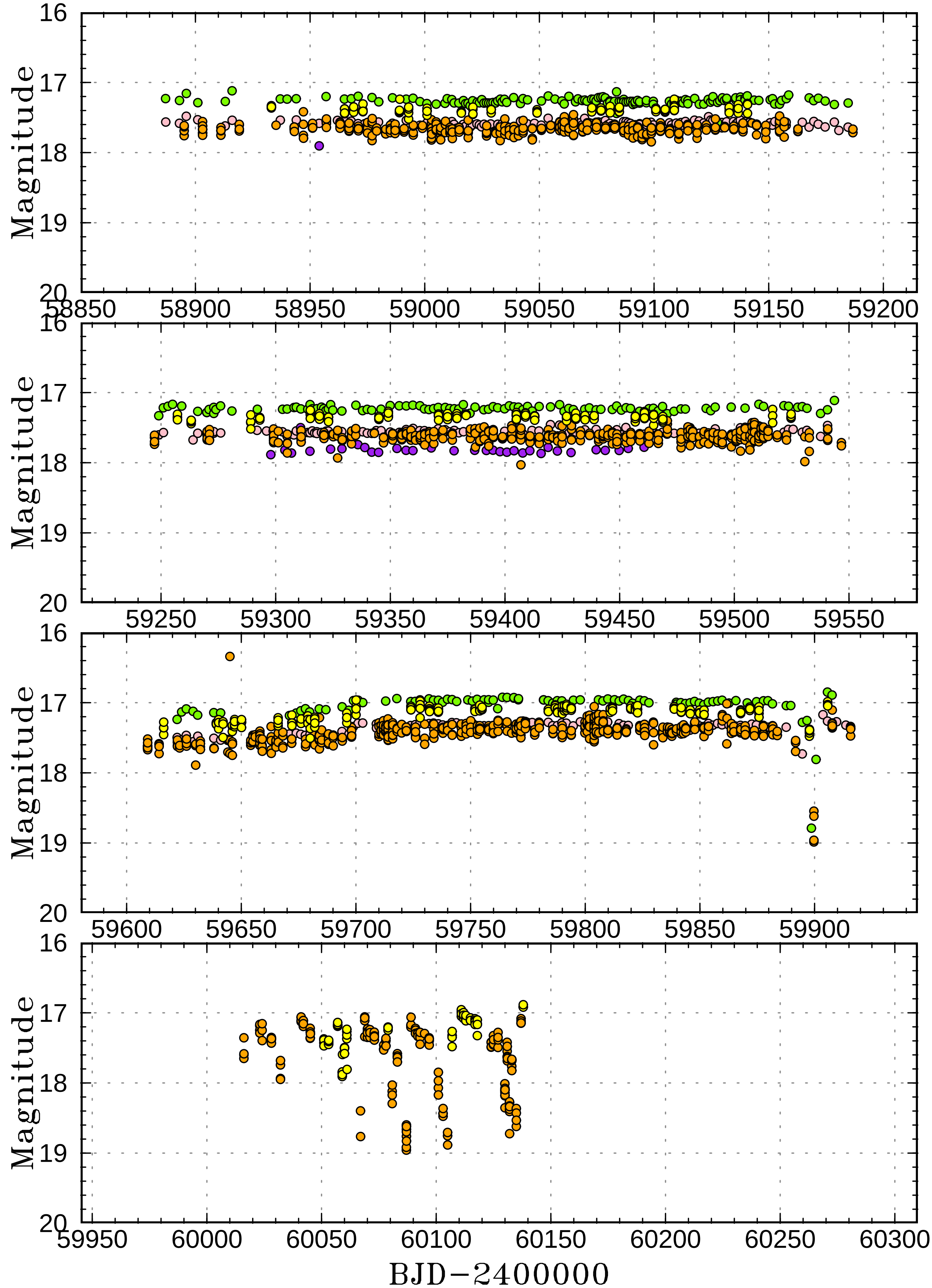

Figure 2: Light curve of SDSS J183131.63+420220.2 in 2020–2023. The symbols are the same as in figure 1. The object brightened somewhat in 2022 (third panel) with a sudden short drop near the end. The object was in dwarf nova (ER UMa) phase in 2023 (last panel).

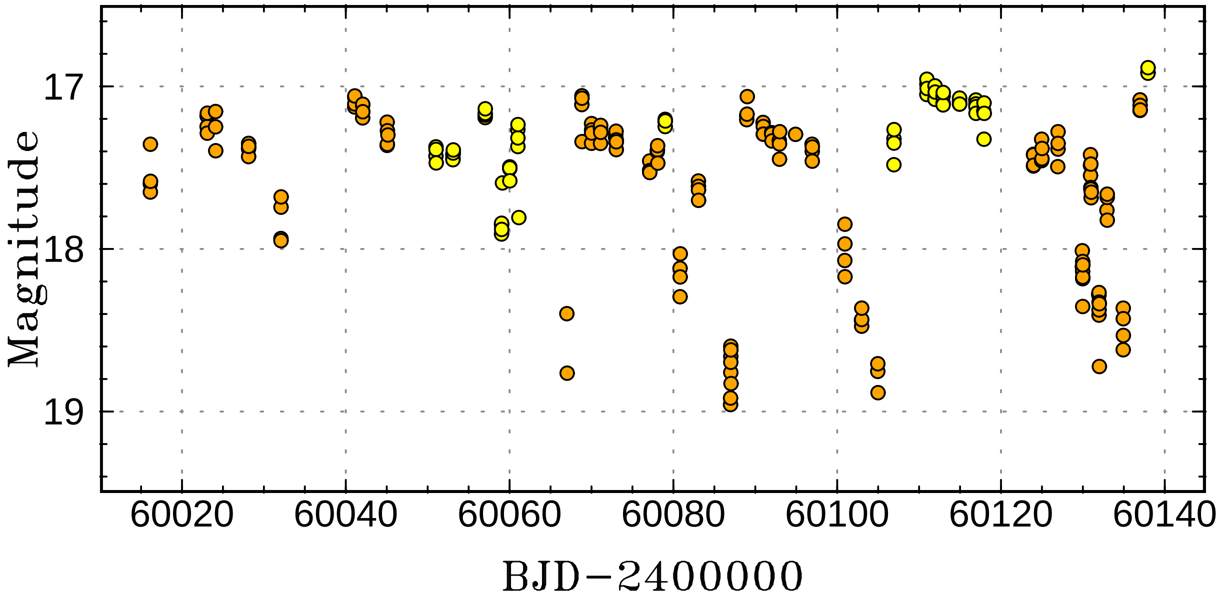

Figure 3: Enlargement of the light curve of SDSS J183131.63+420220.2 in 2023. The symbols are the same as in figure 1. Long outbursts were intervened by short fading episodes. Short outbursts are also also evident around BJD 2460131 and 2460133.

a period of 0.01602343(1) d (figure 4) using the phase dispersion minimization (PDM: Stellingwerf 1978) method after removing long-term trends by using locally-weighted polynomial regression (LOWESS: Cleveland 1979). The error was estimated by the methods of Fernie (1989); Kato et al. (2010). There was no other candidate period in the period region acceptable for an AM CVn star. This period is likely either the orbital or superhump period of this system. I consider the former more likely based on the long coherence. If the period is the orbital period, a superhump signal ∼1% different from this can be expected. I could not find such a signal. The period in SDSS J183131.63+420220.2 is very close to the superhump period [0.015824(9) d] of MGAB-V240. It is most likely that the limit of the thermal stability in the disks of AM CVn stars is around these periods, as expected from the disk-instability theory (Tsugawa and Osaki 1997; Solheim 2010; Kotko et al. 2012).

The long-term variation during the standstill probably requires long-term slight variation of the mass-transfer rate, as is usually considered as the origin of standstills in hydrogen-rich Z Cam stars (Meyer and Meyer-Hofmeister 1983). I also point out that the gradually rising standstill (2017 to 2021) and brightening in late 2022 before its termination are somewhat similar to the IW And stars (hydrogen-rich systems) (Szkody et al. 2013; Kato 2019). The time scales in SDSS J183131.63+420220.2, however, would be too long compared to the viscous time scale of the disk to be considered as the same origin as in IW And stars.

Acknowledgements

This work was supported by JSPS KAKENHI Grant Number 21K03616.

I am grateful to Naoto Kojiguchi for helping downloading the ZTF data and the ATLAS and ZTF teams for making their data available to the public.

This work has made use of data from the Asteroid Terrestrial-impact Last Alert System (ATLAS) project. The ATLAS project is primarily funded to search for near earth asteroids through NASA grants NN12AR55G, 80NSSC18K0284, and 80NSSC18K1575; byproducts of the NEO search include images and catalogs from the survey area. This work was partially funded by Kepler/K2 grant J1944/80NSSC19K0112 and HST GO-15889, and STFC grants ST/T000198/1 and ST/S006109/1. The ATLAS science products have been made possible through the contributions of the University of Hawaii Institute for Astronomy, the Queen's University Belfast, the Space Telescope Science Institute, the South African Astronomical Observatory, and The Millennium Institute of Astrophysics (MAS), Chile.

Based on observations obtained with the Samuel Oschin 48-inch Telescope at the Palomar Observatory as

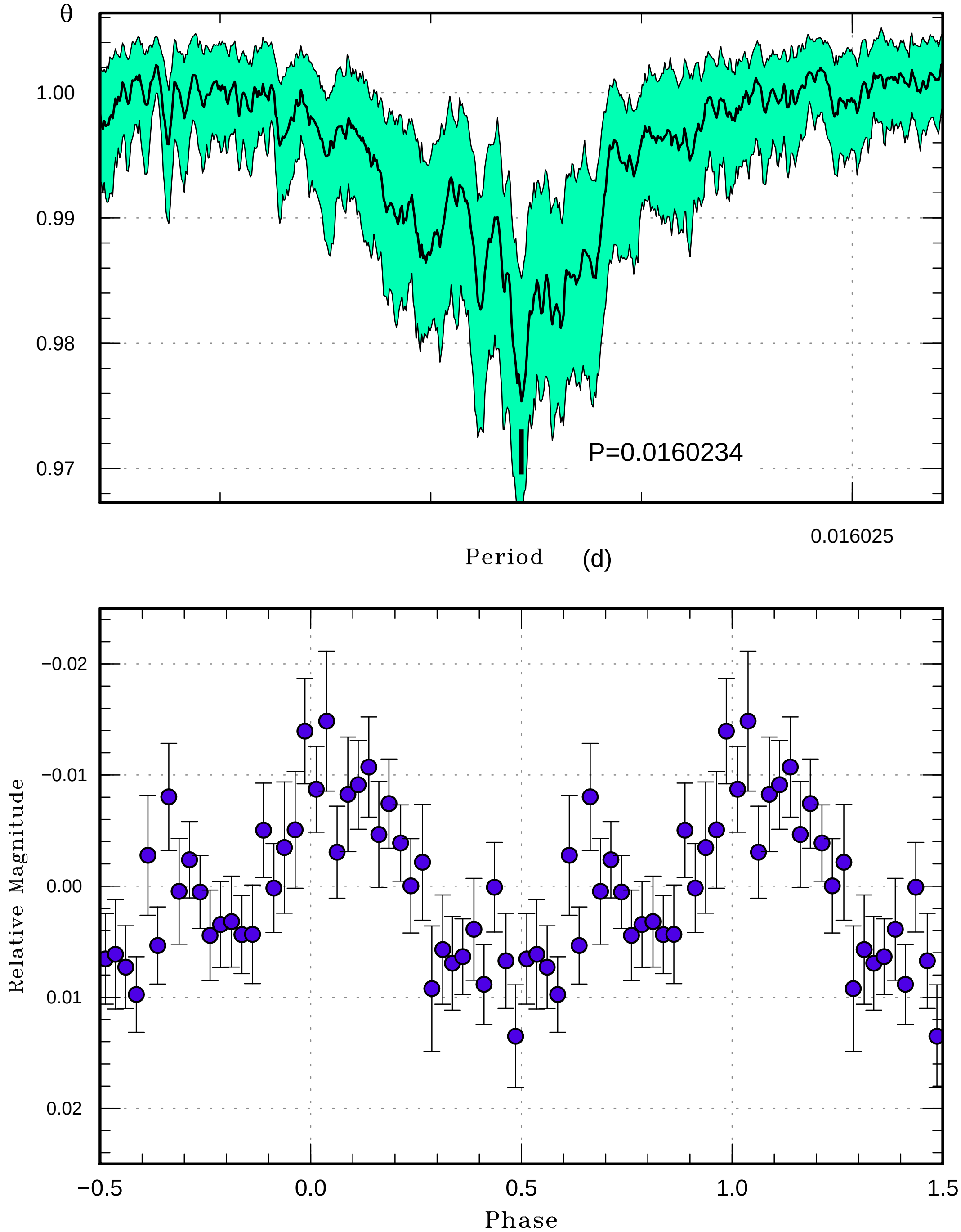

Figure 4: Period analysis of SDSS J183131.63+420220.2 during the standstill. (Upper): PDM analysis. The bootstrap result using randomly contain 50% of observations is shown as a form of 90% confidence intervals in the resultant θ statistics. (Lower): Phase plot.

part of the Zwicky Transient Facility project. ZTF is supported by the National Science Foundation under Grant No. AST-1440341 and a collaboration including Caltech, IPAC, the Weizmann Institute for Science, the Oskar Klein Center at Stockholm University, the University of Maryland, the University of Washington, Deutsches Elektronen-Synchrotron and Humboldt University, Los Alamos National Laboratories, the TANGO Consortium of Taiwan, the University of Wisconsin at Milwaukee, and Lawrence Berkeley National Laboratories. Operations are conducted by COO, IPAC, and UW.

The ztfquery code was funded by the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (grant agreement n°759194 – USNAC, PI: Rigault).

List of objects in this paper

CR Boo, Z Cam, AM CVn, RZ LMi, SU UMa, ER UMa, ATO J277.8818+42.0389, Gaia DR3 2111270034246759424, MGAB-V240, SDSS J183131.63+420220.2, ZTF J183131.63+420220.1

References

Cleveland, W. S. (1979) Robust locally weighted regression and smoothing scatterplots. *J. Amer. Statist. Assoc.* **74**, 829

Fernie, J. D. (1989) Uncertainties in period determinations. *PASP* **101**, 225

Gaia Collaboration et al. (2022) Gaia Data Release 3. Summary of the contents and survey properties. *preprint* (arXiv:2208.00211)

Girven, J., Gänsicke, B. T., Steeghs, D., & Koester, D. (2011) DA white dwarfs in Sloan Digital Sky Survey Data Release 7 and a search for infrared excess emission. *MNRAS* **417**, 1210

Heinze, A. N. et al. (2018) A first catalog of variable stars measured by the Asteroid Terrestrial-impact Last Alert System (ATLAS). *AJ* **156**, 241

Inight, K. et al. (2023) A catalogue of cataclysmic variables from 20 years of the Sloan Digital Sky Survey with new classifications, periods, trends and oddities. *MNRAS* (arXiv:2304.06749)

Kato, T. (2019) Three Z Cam-type dwarf novae exhibiting IW And-type phenomenon. *PASJ* **71**, 20

Kato, T. (2023) MGAB-V240: 23-min AM CVn star showing both 12-d supercycle and standstills. *VSOLJ Variable Star Bull.* **111**, (arXiv:2302.11148)

Kato, T. et al. (2016) RZ Leonis Minoris bridging between ER Ursae Majoris-type dwarf nova and nova-like system. *PASJ* **68**, 107

Kato, T., Maeda, Y., & Moriyama, M. (2023) Genuine standstill in the AM CVn star CR Boo. *VSOLJ Variable Star Bull.* **107**, (arXiv:2302.04454)

Kato, T. et al. (2010) Survey of period variations of superhumps in SU UMa-type dwarf novae. II. The second year (2009–2010). *PASJ* **62**, 1525

Kato, T., Nogami, D., Baba, H., Masuda, S., Matsumoto, K., & Kunjaya, C. (1999) in Disk Instabilities in Close Binary Systems, ed. S. Mineshige, & J. C. Wheeler (Tokyo: Universal Academy Press) p. 45

Kleinman, S. J. et al. (2013) SDSS DR7 white dwarf catalog. *ApJS* **204**, 5

Kotko, I., Lasota, J.-P., Dubus, G., & Hameury, J.-M. (2012) Models of AM Canum Venaticorum star outbursts. *A&A* **544**, A13

Masci, F.-J. et al. (2019) The Zwicky Transient Facility: Data processing, products, and archive. *PASP* **131**, 018003

Meyer, F., & Meyer-Hofmeister, E. (1983) A model for the standstill of the Z Camelopardalis variables. *A&A* **121**, 29

Ofek, E. O., Soumagnac, M., Nir, G., Gal-Yam, A., Nugent, P., Masci, F., & Kulkarni, S. R. (2020) A catalogue of over 10 million variable source candidates in ZTF Data Release 1. *MNRAS* **499**, 5782

Solheim, J. (2010) AM CVn stars: Status and challenges. *PASP* **122**, 1133

Stellingwerf, R. F. (1978) Period determination using phase dispersion minimization. *ApJ* **224**, 953

Szkody, P. et al. (2013) A study of the unusual Z Cam systems IW Andromedae and V513 Cassiopeia. *PASP* **125**, 1421

Tonry, J. L. et al. (2018) ATLAS: A High-cadence All-sky Survey System. *PASP* **130**, 064505

Tsugawa, M., & Osaki, Y. (1997) Disk instability model for the AM Canum Venaticorum stars. *PASJ* **49**, 75

VSOLJ
c/o Keiichi Saijo National Science Museum, Ueno-Park, Tokyo Japan

Editor Seiichiro Kiyota
e-mail:skiyotax@gmail.com