No.104 Jan. 2023

ISSN 0917-2211

Variable Star Bulletin

Very low state in PY Per in 2022

Taichi Kato[1]

tkato@kusastro.kyoto-u.ac.jp

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

Received 2023 Jan. 02

Abstract

Using VSNET, VSOLJ, ASAS-SN and ATLAS observations, I found that the Z Cam star PY Per spent a long, faint low state reaching 19.1 mag at least between 2022 June and November. No dwarf nova outburst was recorded during this interval. TESS data during this low state showed two maxima in one orbital cycle and can be interpreted as an ellipsoidal modulation arising from the secondary. These observations suggest that the mass-transfer almost stopped during this low state and strengthen the identification of PY Per as a VY Scl star. PY Per had shown an unusual outburst resembling an SU UMa-type superoutburst less than half a year before (Kato 2022, arXiv:2204.12056) and these phenomena may have been physically related.

In Kato (2022), I reported the detection of an outburst (2021 December–2022 January) resembling an SU UMa-type superoutburst in the Z Cam star PY Per with an orbital period of 0.15468(5) d (Kato 2022; Taylor and Thorstensen 1996). Kato (2022) also detected faint states in observations by the American Association of Variable Stars (AAVSO), and showed that this object is also an VY Scl-type cataclysmic variable (CV) [see e.g., Warner (1995) for CVs in general and their subtypes]. VY Scl-type faint states are sometimes associated with Z Cam stars, most notably the 1996–1997 totally unexpected long-lasting fading in RX And (Sion et al. 2001; Kato et al. 2002; Schreiber et al. 2002; Kato 2004).

After the solar conjunction following the unusual outburst mentioned above, I noticed that PY Per was in low state without any outburst in Variable Star Observers League in Japan (VSOLJ) and VSNET (Kato et al. 2004) observations (vsnet-alert 27029.[1]). This has been confirmed by using the All-Sky Automated Survey for Supernovae (ASAS-SN) Sky Patrol (Shappee et al. 2014; Kochanek et al. 2017) data. These observations started in 2022 June (ASAS-SN) and 2022 July (VSOLJ). Using the data by the Asteroid Terrestrial-impact Last Alert System (ATLAS: Tonry et al. 2018; Heinze et al. 2018; Smith et al. 2020) Forced Photometry (Shingles et al. 2021)[2], I further confirmed that the 2022 fading episode was the deepest (reaching 19.1 mag) and longest (more than 150 d) ever recorded in this object (figure 1).

For a comparison, a light curve of the preceding seasons is given in figure 2. In the 2019–2020 season (before BJD 2458950), the object showed frequent low-amplitude outbursts as was typical for a Z Cam star. The behavior was similar to this at least between 2016 and 2019. In the 2020–2021 season (BJD 2459030–2459290), the quiescence became fainter (near 18.0 mag) and longer and brighter outbursts in addition to smaller ones became more prominent than in the previous season. Although the quiescent brightness (18.0 mag) was almost as faint as the VY Scl-type low state mentioned in Kato (2022), the object definitely showed dwarf nova-type outbursts. The light curve in 2020–2021 probably illustrated the behavior when the mass-transfer rate decreased.

Compared to the 2020–2021 season, the mass-transfer rate probably returned normal in the 2021–2022 season (left part of figure 1). There was, however, an interval lacking outbursts (BJD 2459525–2459568), but not as faint as the 2020–2021 quiescence, preceding the unusual outburst resembling an SU UMa-type superoutburst. Accumulation of matter in the disk during this interval may have caused the unusual outburst. Although this

[1] <http://ooruri.kusastro.kyoto-u.ac.jp/mailarchive/vsnet-alert/27029>
[2] The ATLAS Forced Photometry is available at <https://fallingstar-data.com/forcedphot/>.

unusual outburst may have been physically related to the very faint low state in 2022, observations were impossible due to the solar conjunction and how this very faint state started remains a mystery. Note that the 1996–1997 low state in RX And was preceded by an unusually long standstill. These rare phenomena might have been physically related and the case would also be suspected in PY Per.

I analyzed Transiting Exoplanet Survey Satellite (TESS) observations obtained in 2022.[3] The full light-curve is available at the Mikulski Archive for Space Telescope (MAST[4]). The TESS observations started on 2022 October 28 (BJD 2459882) and ended on 2022 November 26 (BJD 2459910). PY Per started rising in the TESS data on the final two days. Since most of the TESS data were obtained when PY Per was in deep low state and since the object has nearby (unrelated) contaminating stars, I did not attempt to extract the flux of PY Per but used the flux combined with contaminating stars. Using the data before BJD 2459908.6 (object in low state), I could detect the orbital period and modulations (figure 3). The period was determined to be 0.15453(2) d with the Phase Dispersion Minimization (PDM, Stellingwerf 1978) method after removing long-term trends by locally-weighted polynomial regression (LOWESS: Cleveland 1979). The errors of periods by the PDM method were estimated by the methods of Fernie (1989) and Kato et al. (2010). Although the obtained period is in agreement with that obtained in high state in Kato (2022), the orbital profile is very different. In high state, there was a single peak in one orbit [figure 3 in Kato (2022)], while the current observations clearly show two maxima in one orbit. This feature most likely represents an ellipsoidal variation of the secondary and TESS photometry supports the very weak (or no) contribution from the accretion disk. These observations support that the mass accretion almost stopped in this very low state in PY Per and strengthen the identification of this object as a VY Scl star.

Acknowledgements

This work was supported by JSPS KAKENHI Grant Number 21K03616. The author is grateful to the ASAS-SN, ATLAS and TESS teams for making their data available to the public. I am grateful to VSOLJ and VSNET observers for reporting observations and to Naoto Kojiguchi for providing a script for downloading TESS data. The contributors from VSNET and VSOLJ in 2022 were Pavol A. Dubovsky, Masao Funada, Hiroshi Itoh, Eddy Muyllaert, Yutaka Maeda, Masayuki Moriyama and Gary Poyner.

This work has made use of data from the Asteroid Terrestrial-impact Last Alert System (ATLAS) project. The Asteroid Terrestrial-impact Last Alert System (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.

List of objects in this paper

RX And, Z Cam, PY Per, VY Scl, SU UMa

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

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

Kato, T. (2004) Detection of short fading episodes in two dwarf novae from VSNET observations. *PASJ* **56**, S55

[3] <https://tess.mit.edu/observations/>.
[4] <http://archive.stsci.edu/>.

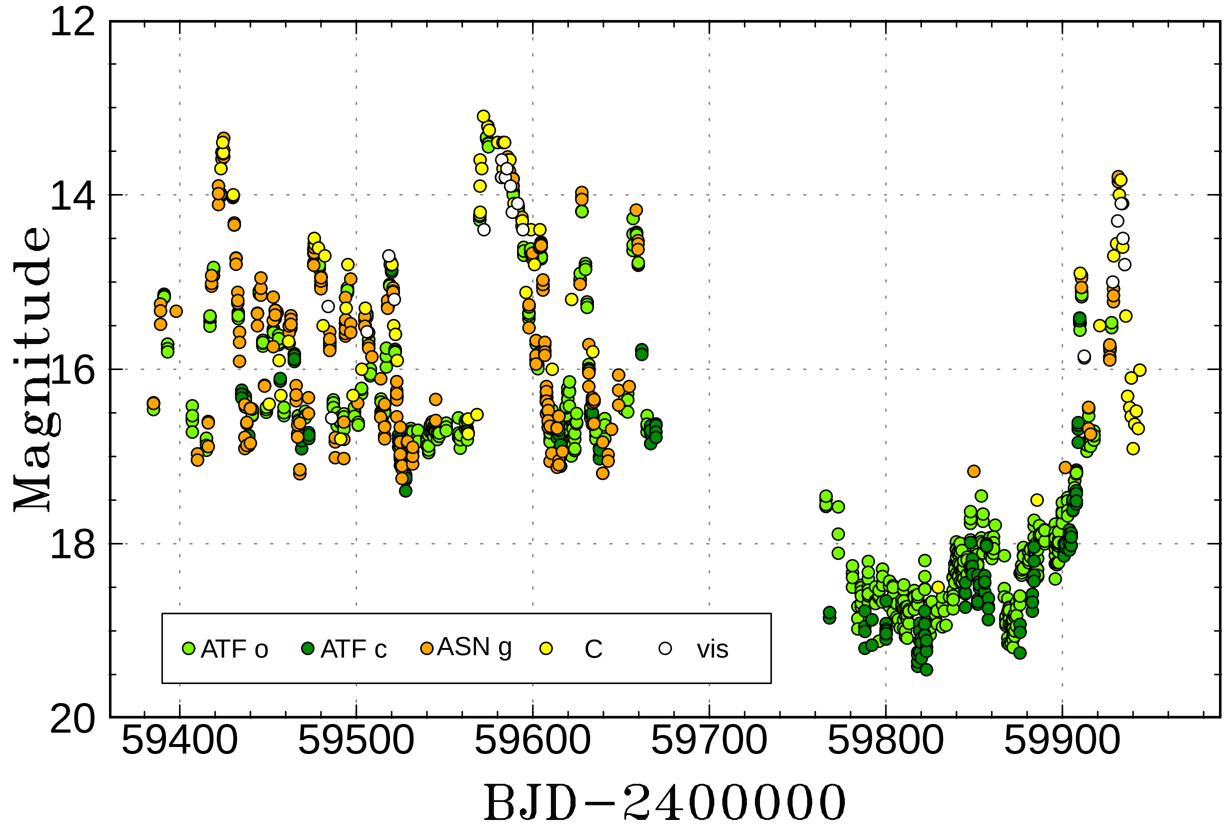

Figure 1: 2021–2022 light curve of PY Per using ATLAS forced photometry (ATF), ASAS-SN (ASN), VSOLJ and VSNET (C for CCD close to visual and vis for visual) observations. The left part of this figure corresponds to the fourth panel of Fig. 1 in Kato (2022). The outburst resembling an SU UMa-type superoutburst started on BJD 2459570. After the solar conjunction, the object was found already in a deep, low state below 18 mag. The object gradually started to brighten after BJD 2459880 and there was a short outburst on BJD 2459910. A more ordinary outburst started on BJD 2459927, which slowly rose to a maximum of 13.8 mag.

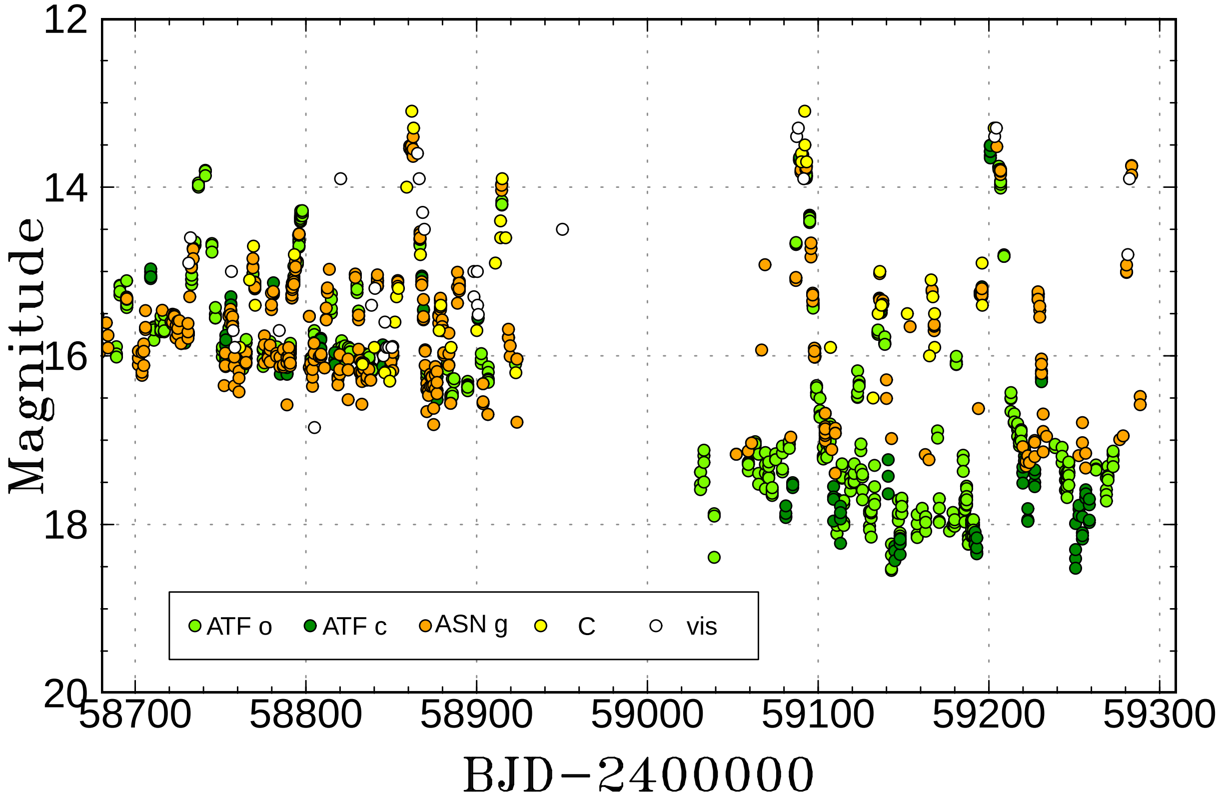

Figure 2: Light curve of PY Per in the 2019–2021 season. The symbols are the same as in figure 1. In the 2019–2020 season (before BJD 2458950), the object showed frequent low-amplitude outbursts as was typical for a Z Cam star. In the 2020–2021 season (BJD 2459030–2459290), the quiescence became fainter (near 18.0 mag) and longer and brighter outbursts in addition to smaller ones became more prominent than in the previous season.

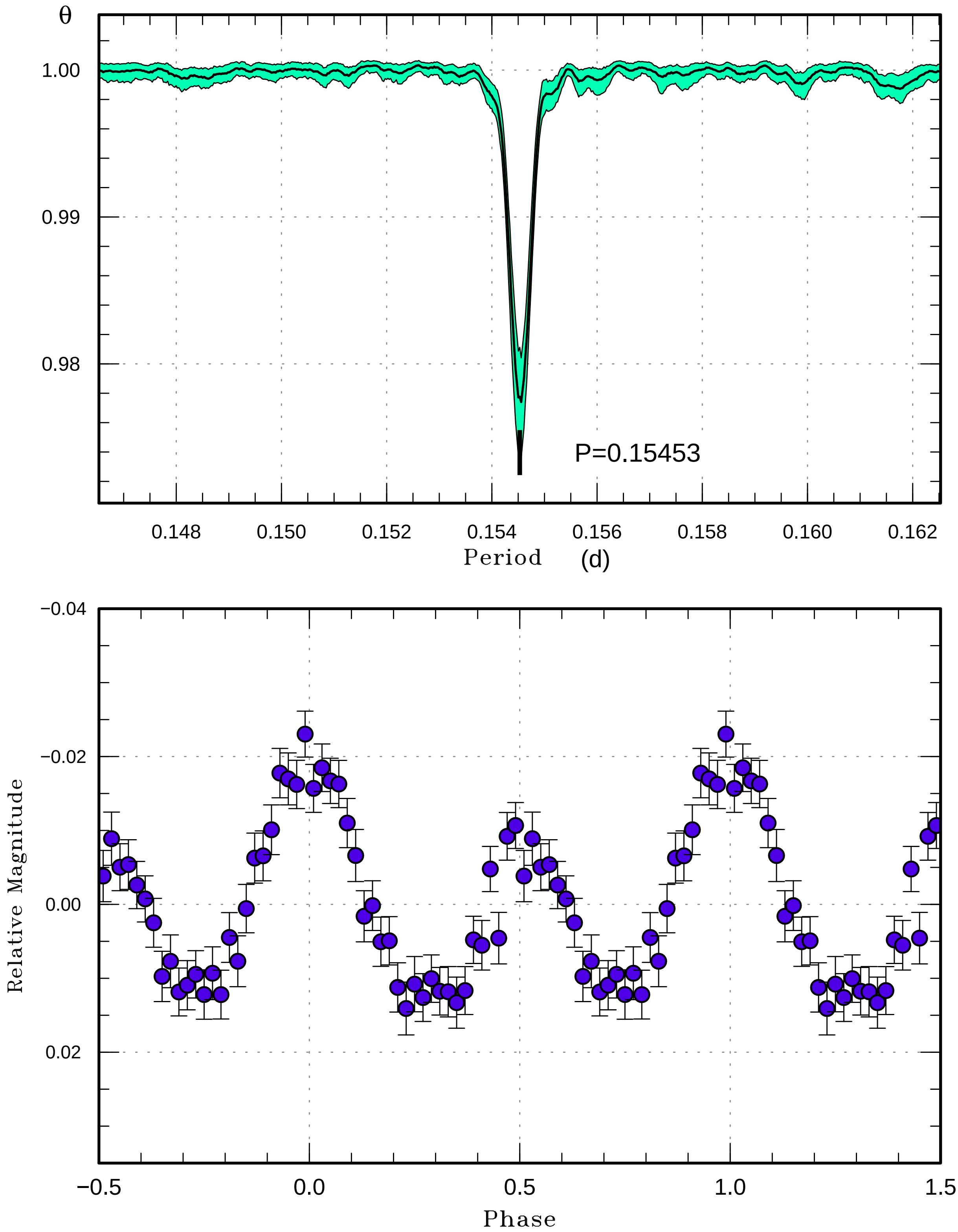

Figure 3: Period analysis of the TESS data during the low state. (Upper): We analyzed 100 samples which randomly contain 50% of observations, and performed the PDM analysis for these samples. The bootstrap result is shown as a form of 90% confidence intervals in the resultant PDM θ statistics. (Lower): Orbital variation. Two peaks in one orbit are clearly visible. Note that the amplitude was smaller than real due to the contaminating stars.

Kato, T. (2022) Z Cam star PY Per in SU UMa state? *VSOLJ Variable Star Bull.* **100**, (arXiv:2204.12056)

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., & Masuda, S. (2002) Extended deep minimum and subsequent brightening of RX And in 1996–1997. *PASJ* **54**, 575

Kato, T., Uemura, M., Ishioka, R., Nogami, D., Kunjaya, C., Baba, H., & Yamaoka, H. (2004) Variable Star Network: World center for transient object astronomy and variable stars. *PASJ* **56**, S1

Kochanek, C. S. et al. (2017) The All-Sky Automated Survey for Supernovae (ASAS-SN) light curve server v1.0. *PASP* **129**, 104502

Schreiber, M. R., Gänsicke, B. T., & Mattei, J. A. (2002) RX And: An intermediate between Z Cam and VY Scl stars. *A&A* **384**, L6

Shappee, B. J. et al. (2014) The man behind the curtain: X-rays drive the UV through NIR variability in the 2013 AGN outburst in NGC 2617. *ApJ* **788**, 48

Shingles, L. et al. (2021) Release of the ATLAS Forced Photometry server for public use. *Transient Name Server AstroNote* **7**, 1

Sion, E. M., Szkody, P., Gaensicke, B., Cheng, F. H., La Dous, C., & Hassall, B. (2001) Hubble Space Telescope spectroscopy of the dwarf nova RX Andromedae. I. the underlying white dwarf. *ApJ* **555**, 834

Smith, K. W. et al. (2020) Design and operation of the ATLAS Transient Science Server. *PASP* **132**, 085002

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

Taylor, C. J., & Thorstensen, J. R. (1996) Orbital periods of the dwarf novae AR And, AM Cas, and PY Per. *PASP* **108**, 894

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

Warner, B. (1995) Cataclysmic Variable Stars (Cambridge: Cambridge University Press)

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

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