

# Variable Star Bulletin

## Z Cam star PY Per in SU UMa state?

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### Abstract

PY Per has been known as a Z Cam star. Using VSOLJ, VSNET, AAVSO, ASAS-SN and ZTF observations, I found that this object experienced faint states and classified it to be a Z Cam + VY Scl star. Furthermore, the object changed the outburst behavior since 2020 and it has been showing regularly recurring long, bright outbursts with cycles of 110–160 d and short, faint outbursts between them. The 2021 December–2022 January outburst particularly resembled a superoutburst with a gradually fading plateau phase having a duration more than 25 d and two rebrightenings in the fading part. This object has a long orbital period of 0.15468(5) d based on the TESS data and the previous radial-velocity study. The existence of a superoutburst in a system with a long orbital period would be unusual, but not unprecedented. Since the phenomenon may still be ongoing, I draw attention to this object when it emerges from in the morning sky after the solar conjunction.

PY Per was discovered by Hoffmeister (1966) (S 9160) as an RW Aur star (the type currently known as pre-main sequence rapid irregular variables or the GCVS type “IS”) with a photographic range of 14–16.5 mag. Hoffmeister (1966) made a remark that the star was not particularly colored and that the amplitudes on Sonneberg plates were 1.5–2 mag. Bond (1978) systematically studied high-latitude blue variables and found that PY Per had diffuse (i.e. broad) hydrogen emission lines, superposed on a blue continuum. Bond (1978) classified PY Per as a possible dwarf nova. Zwitter and Munari (1994) obtained a low-resolution spectrum and confirmed the finding by Bond (1978). Taylor and Thorstensen (1996) obtained a radial-velocity study and found an orbital period ( $P_{\text{orb}}$ ) of 0.15480(17) d. Taylor and Thorstensen (1996) pointed out that PY Per was very faint ( $V \sim 19.8$ ) on an image in Downes and Shara (1993).

Although this object has been known as a Z Cam star and was relatively well observed by the American Association of Variable Stars (AAVSO) members particularly between 2003 and 2017, the coverage has not been good as in the past in recent years. During the period of intensive observations by the AAVSO, the object showed both bright and faint states and the faint states apparently lasted more than a year, particularly in late 2008 to 2009. During this faint state, there was no detected outburst and the object can be classified as a Z Cam+VY Scl star. During bright states, the range of variation was relatively small (14.0–17.0), which probably corresponded to the state observed by Hoffmeister (1966). The faint record on an image in Taylor and Thorstensen (1996) was not that faint and was brighter than 19.0 compared to Gaia EDR3 magnitudes of nearby stars (Gaia Collaboration et al. 2021). The state when the image in Downes and Shara (1993) was obtained was probably similar to faint states recently observed.

I noticed that the outburst behavior changed dramatically since 2020, when relatively regularly recurring long, bright outbursts with cycles of 110–160 d and short, faint outbursts between them dominated in the light curve (figure 1). I used the All-Sky Automated Survey for Supernovae (ASAS-SN) Sky Patrol data (Shappee et al. 2014;

Kochanek et al. 2017), the Zwicky Transient Facility (ZTF: Masci et al. 2019) data<sup>1</sup>, observations by AAVSO International Database<sup>2</sup>, Variable Star Observers League in Japan (VSOLJ) and VSNET (Kato et al. 2004). The pattern even looks like that of an SU UMa star. The long outburst in 2021 December–2022 January gradually faded and had a duration more than 25 d, which was unexpectedly long, and even had two rebrightenings on the fading phase (figure 2). This outburst particularly looks like a superoutburst.

I also analyzed Transiting Exoplanet Survey Satellite (TESS) observations.<sup>3</sup> The full light-curve is available at the Mikulski Archive for Space Telescope (MAST<sup>4</sup>). The TESS observations were obtained in 2019 November (BJD 2458790–2458814), when the amplitudes of dwarf nova-type variations were small. The  $P_{\text{orb}}$  was determined to be 0.15468(5) d by using the Phase Dispersion Minimization (PDM, Stellingwerf 1978) method after removing long-term trends by locally-weighted polynomial regression (LOWESS: Cleveland 1979) (figure 3). The errors of periods by the PDM method were estimated by the methods of Fernie (1989) and Kato et al. (2010). This result confirmed and slightly refined the value in Taylor and Thorstensen (1996). There was no hint of positive or negative superhumps.

If PY Per indeed showed a superoutburst, it is unusual for an object with  $P_{\text{orb}}$  of 0.15468(5) d. There is, however, a confirmed case of BO Cet with  $P_{\text{orb}}=0.1398$  d (Kato et al. 2021). A suspected case of ASASSN-14ho [ $P_{\text{orb}}=0.24315(10)$  d, Gasque et al. 2019] with multiple rebrightenings has also been reported (Kato 2020). Although there was apparently no time-resolved photometry during the 2021 December–2022 January outburst and the object has already gone into solar conjunction, I would like to call attention to this object to see whether this state continues when the object emerges in the morning sky and if it is the case, time-resolved photometry during a long, bright outburst is desired. It is known that SU UMa stars with long  $P_{\text{orb}}$  can have three types of outbursts (normal, long normal and superoutbursts) as in TU Men (Warner 1995; Bateson et al. 2000), NY Ser (Pavlenko et al. 2014) and V1006 Cyg (Kato et al. 2016; Pavlenko et al. 2018). The difference in the durations of long outbursts in PY Per after 2020 may reflect different types of outbursts and only the 2021 December–2022 January might have been a genuine superoutburst.

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## List of objects in this paper

RW Aur, BO Cet, Z Cam, V1006 Cyg, TU Men, PY Per, VY Scl, ASASSN-14ho

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<sup>1</sup>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](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>>.

<sup>2</sup><<http://www.aavso.org/data-download>>.

<sup>3</sup><<https://tess.mit.edu/observations/>>.

<sup>4</sup><<http://archive.stsci.edu/>>.

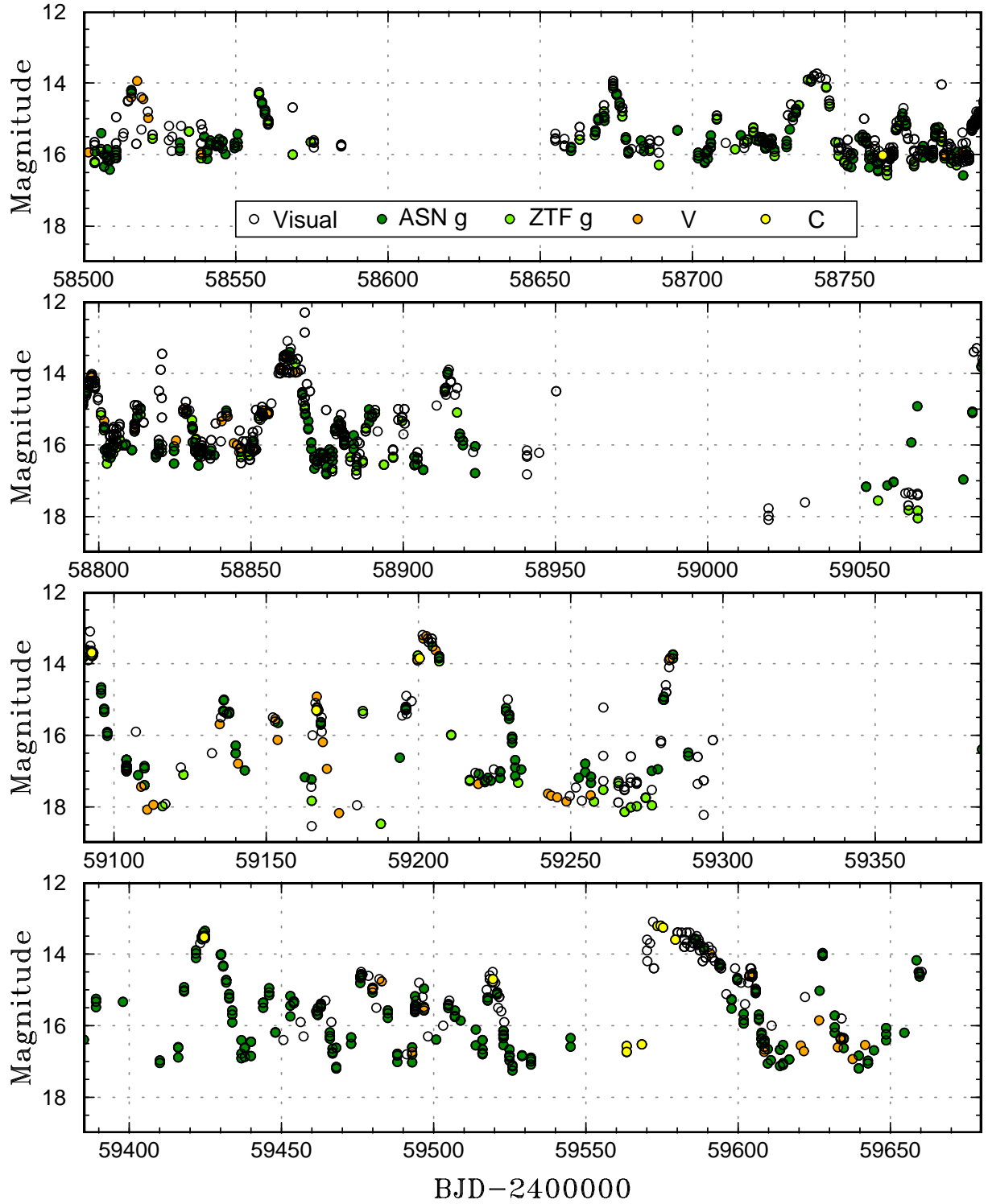


Figure 1: Long-term light curve of PY Per using VSOLJ, VSNET, AAVSO, ASAS-SN and ZTF observations. The object showed low-amplitude outbursts before 2020 (the first and second panels). The outburst pattern changed since then and the behavior in the bottom panel resembles that of an SU UMa star in that long, bright outbursts occur in addition to short, faint outbursts.

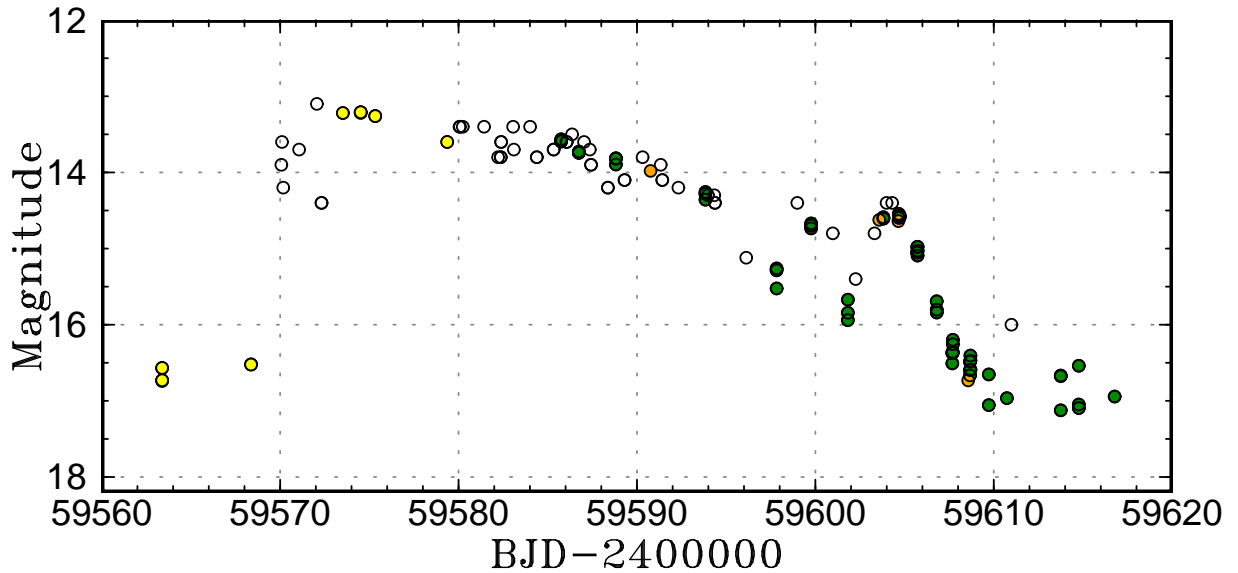


Figure 2: Enlargement of the 2021 December–2022 January long and bright outburst of PY Per. There were apparently two rebrightenings during the fading phase of the outburst. The symbols are the same as in figure 1.

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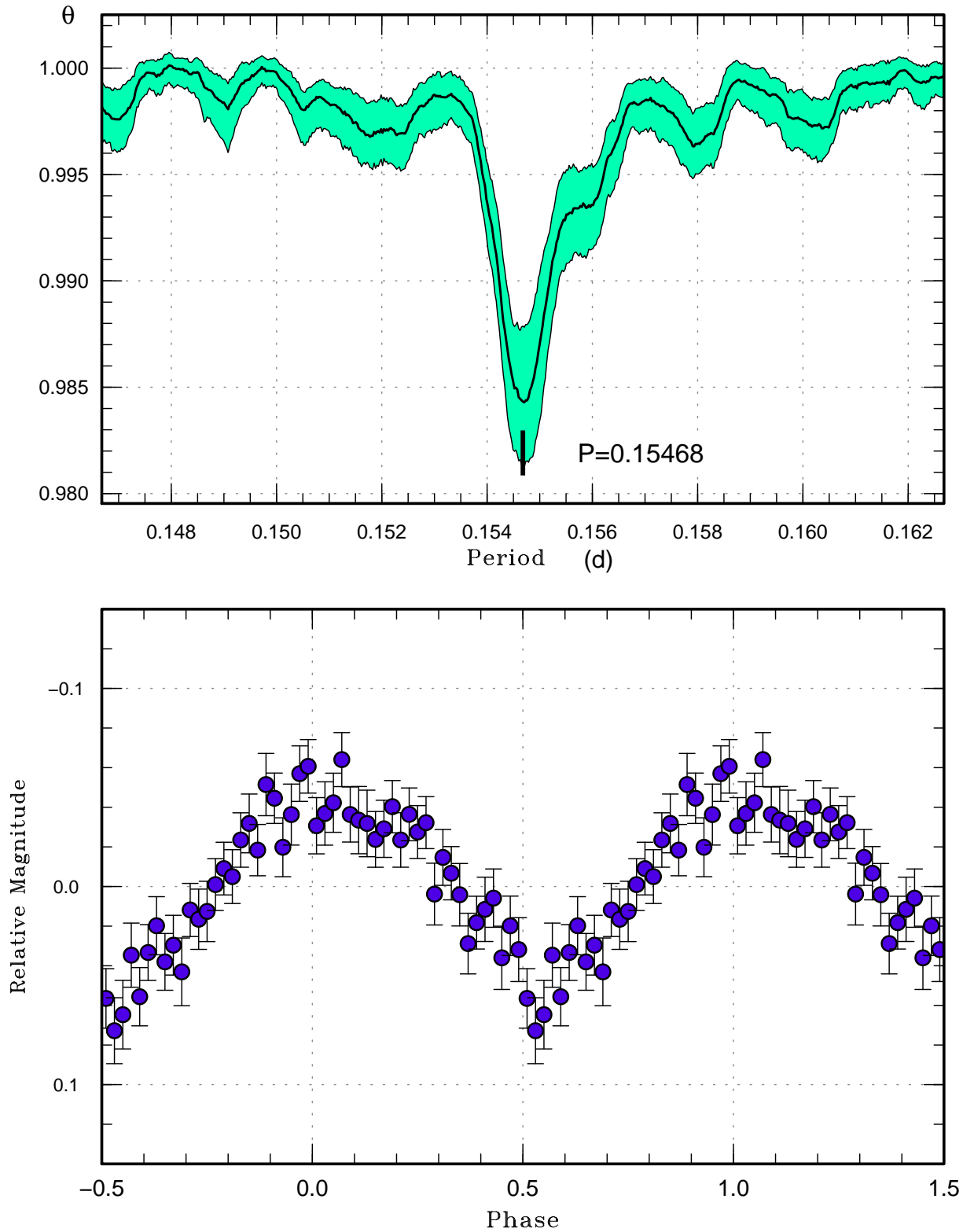


Figure 3: Period analysis of the TESS data. (Upper): We analyzed 100 samples which randomly contain 50% of observations, and performed the PDM analysis for these samples. The bootstrap result is shown as a form of 90% confidence intervals in the resultant PDM  $\theta$  statistics. (Lower): Orbital variation.

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