No.81 Sep. 2021

ISSN 0917-2211

Variable Star Bulletin

Orbital and spin periods of the candidate white dwarf pulsar ASASSN-V J205543.90+240033.5

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Received 2021 Sep. 09

Abstract

ASASSN-V J205543.90+240033.5 has been suggested to be a white dwarf pulsar by Kato (2021, arXiv:2108.09060). We obtained time-resolved photometry and identified the orbital and spin periods to be 0.523490(1) d and 0.00678591(1) d = 9.77 min, respectively. These values strengthen the similarity of this object with AR Sco. We estimated that the strength of the spin pulse is 3.6 times smaller than in AR Sco.

1 Introduction

ASASSN-V J205543.90+240033.5 is a variable object detected by the All-Sky Automated Survey for Supernovae (ASAS-SN, Shappee et al. 2014, Kochanek et al. 2017). This object was also independently listed as a candidate RR Lyr star by Sesar et al. (2017) using the Panoramic Survey Telescope and Rapid Response System (Pan-STARRS1, Chambers et al. 2016). It was also independently listed as a variable star ATO J313.9329+24.0092 by Heinze et al. (2018) using the Asteroid Terrestrial-impact Last Alert System (ATLAS, Tonry et al. 2018) data. In Kato (2021), one of the authors (TK) reported superimposed long and short periods and suggested that this object could be a white dwarf pulsar similar to AR Sco (Marsh et al. 2016; Stiller et al. 2018).

2 Observation and true orbital period

Following this suggestion, FJH reported time-resolved photometry on seven consecutive night between 2021 August 24 and 30 using a 50-cm telescope located in San Pedro de Atacama (Chile). The total number of observations was 979 and the time resolution was 96 s. EP and AS also supplied a light curve using the 2.6-meter reflector (Shajn Telescope, ZTSh) in Crimea. EP suggested that the orbital period would be longer than the 0.2 d one suggested by TK in vsnet-alert 26186.[1]

[1] <http://ooruri.kusastro.kyoto-u.ac.jp/mailarchive/vsnet-alert/26186 >.

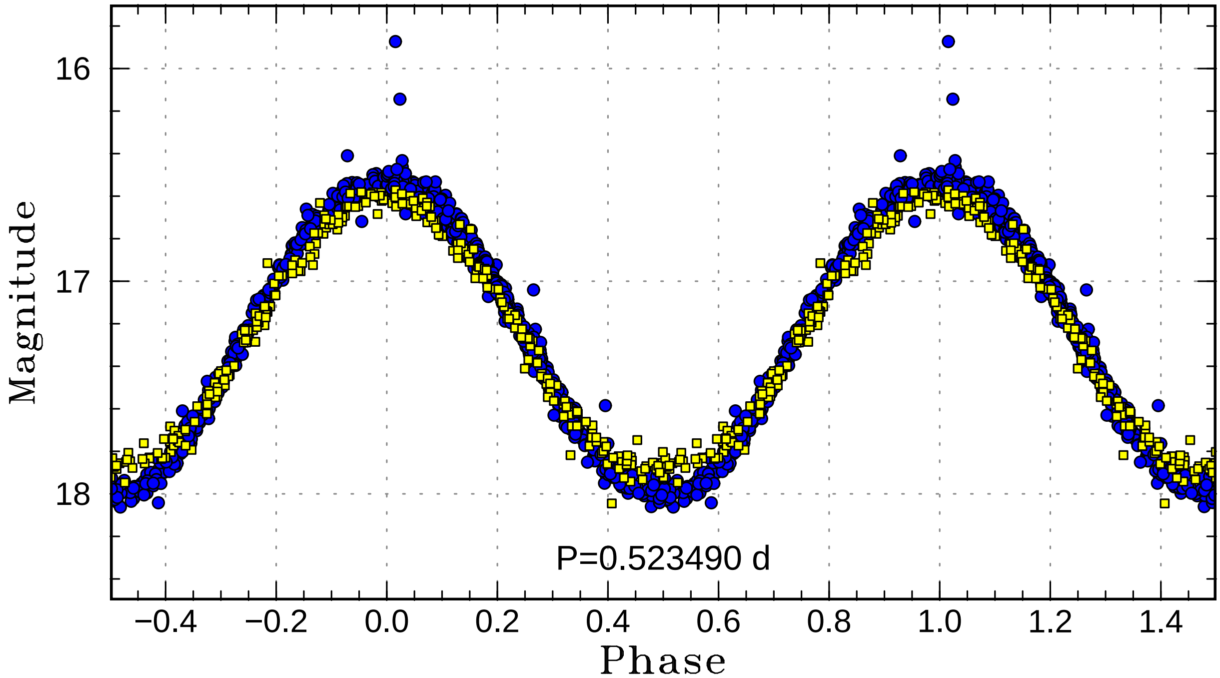

Figure 1: Phase-folded variations of ASASSN-V J205543.90+240033.5 in the ZTF data. Filled circles and squares represent ZTF r and g observation, respectively. The epoch was chosen as BJD 2458773.24.

We reanalyzed the data from Public Data Release 6 of the Zwicky Transient Facility (Masci et al., 2019) observations[2] and found that the true orbital period is 0.523490(1) d (first announced in vsnet-alert 26206[3]), not 10.803(2) d as reported in Kato (2021). The period and error were determined by the Phase Dispersion Minimization (PDM; Stellingwerf 1978) method and the methods in Fernie (1989) and Kato et al. (2010). Figure 1 shows the phase-folded light curve using the true orbital period. The light curve is almost perfectly sinusoidal and is interpreted as the reflection-type variation caused by strong irradiation from the white dwarf. This period is confirmed to express all the observations by FJH (figure 2). The initially obtained period of 10.803 d was an alias of the 0.523490 d period resulting from the intervals of the nightly ZTF observations.

3 Spin period

ASASSN-V J205543.90+240033.5 showed short-period coherent variation in two ZTF time-resolved runs (Kato, 2021). The periods on the two nights were 0.00675(3) d and 0.00682(2) d. The pulse profile using FJH data is shown in figure 3. Almost sinusoidal 0.06-mag variations were clearly detected. The best period using this data set is 0.0067882(7) d, although there remains a possibility of aliases (such as 0.006742 d). Using this value, we have been able to identify the spin period using the ZTF data (figure 4). The resultant period is 0.00678591(1) d = 9.77 min.

4 Comparison with AR Sco

With the newly determined orbital and spin periods, the similarity between ASASSN-V J205543.90+240033.5 has become more evident (table 1, the periods for AR Sco were taken from Stiller et al. 2018). As seen from the almost zero color index in figure 1, ASASSN-V J205543.90+240033.5 is not very significantly reddened. The Gaia

[2] 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>.

[3] <http://ooruri.kusastro.kyoto-u.ac.jp/mailarchive/vsnet-alert/26206 >.

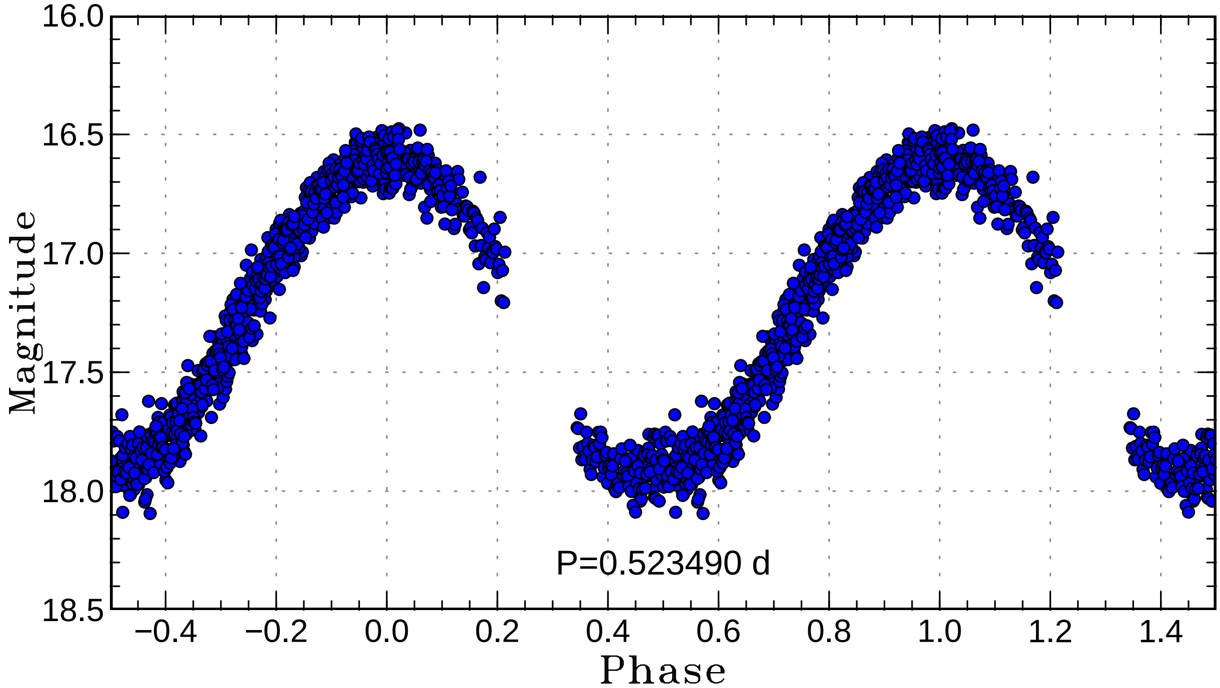

Figure 2: Phase-folded light curve of ASASSN-V J205543.90+240033.5 using time-resolved photometry by FJH. The period and epoch are the same as in figure 1.

Table 1: Comparison between ASASSN-V J205543.90+240033.5 and AR Sco

	ASASSN-V J205543.90+240033.5	AR Sco
Orbital period (d)	0.523490	0.14853528
Spin period (d)	0.00678591	0.00136804584

color $G_{\rm BP} - G_{\rm RP}$ is +0.38 (Gaia Collaboration et al., 2021). Considering that the white dwarf and illuminated hemisphere of the secondary are the dominant source of light, we consider the unreddened color to be around 0. On the other hand, AR Sco is more strongly reddened. The Gaia color $G_{\rm BP} - G_{\rm RP}$ is +1.38. Assuming that the unreddened colors of these two object are around 0, we can estimate extinctions by using the formula $A(G) = 1.89E(G_{\rm BP} - G_{\rm RP})$ (Wang and Chen, 2019). We adopted $A(G)$ values for 0.72 and 2.61 for ASASSN-V J205543.90+240033.5 and AR Sco, respectively. Using Gaia parallaxes (Gaia Collaboration et al., 2021), the unreddened absolute magnitudes (M_G) of these two objects are +5.4 and +7.0, respectively. This indicates that ASASSN-V J205543.90+240033.5 is intrinsically 4.4 times more luminous than AR Sco, which appears to reflect the difference in the orbital period. The mean pulse amplitude is 0.7 mag (90%) in AR Sco (figure 10 in Stiller et al. 2018). Considering that the system is 4.4 times more luminous in ASASSN-V J205543.90+240033.5, the pulse amplitudes (0.06 mag) in the latter corresponds to 25% pulse in AR Sco, which means that the strength of the spin pulse is 3.6 times smaller than in AR Sco. Whether this difference reflects the difference in the emission mechanism needs to be studied by further multiwavelength observations.

Acknowledgments

The author is grateful to Naoto Kojiguchi for supplying a wrapper code for obtaining the ZTF data. The author is also grateful to Yusuke Tampo for processing the VSNET campaign data.

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

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

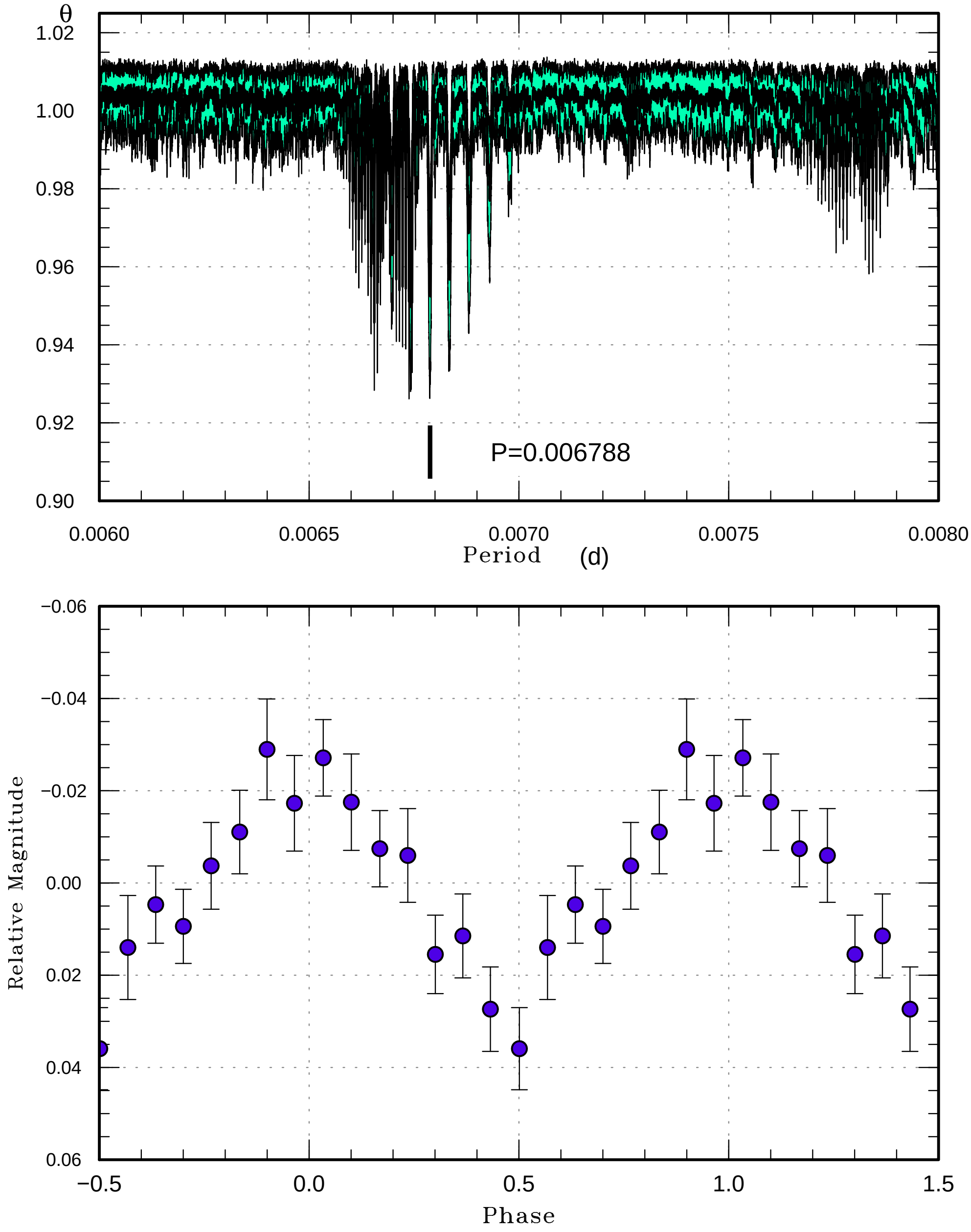

Figure 3: Pulse profile of ASASSN-V J205543.90+240033.5 using FJH data after removing the orbital variation. (Upper): PDM analysis. We analyzed 100 samples which randomly contain 50% of observations, and performed the PDM analysis for these samples. The bootstrap result is shown as a form of 90% confidence intervals in the resultant PDM θ statistics. (Lower): Phase-averaged profile.

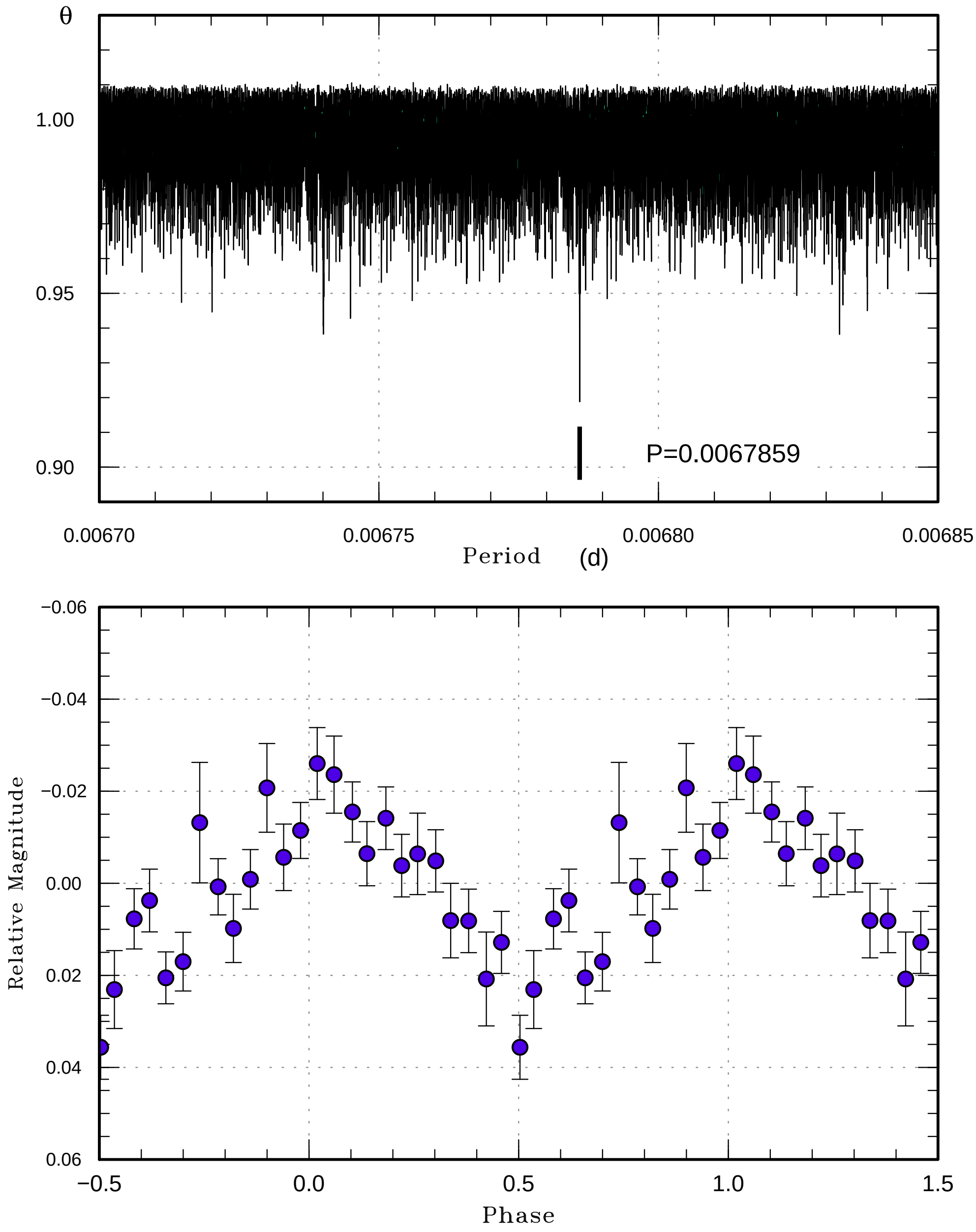

Figure 4: Pulse profile of ASASSN-V J205543.90+240033.5 using the ZTF after removing the orbital variation. (Upper): PDM analysis. (Lower): Phase-averaged profile.

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).

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