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ZTF J185139.81+171430.3 = ZTF18abnbzvx: the second white dwarf pulsar?

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Abstract

We found that ZTF J185139.81+171430.3 = ZTF18abnbzvx shows large-amplitude (0.8 mag) coherent variations with a very short [0.00858995(3) d = 12.37 min] period using Public Data Release of Zwicky Transient Facility observations. The only known object that shows similar very short period, large-amplitude and coherent variations is the unique white dwarf pulsar AR Sco. The variations in ZTF J185139.81+171430.3 may arise from a mechanism as in AR Sco and this object should deserve attention.

ZTF18abnbzvx is a variable object detected by the Zwicky Transient Facility (ZTF) project. The object was classified as a dwarf nova by the Automatic Learning for the Rapid Classification of Events (ALeRCE) Alert Broker (Förster et al., 2021). The object was listed as a candidate variable star (ZTF J185139.81+171430.3, hereafter ZTF J1851) having a range of 17.561–18.836 and a period of 0.0086 d in table 4 of Ofek et al. (2020). Automatic period detections often give spurious periods (either close to 1 d, 0.5 d or very short ones) and such periods are not usually considered seriously.

We used Public Data Release 6 of the Zwicky Transient Facility (Masci et al., 2019) observations[1] and found that this object showed large-amplitude (0.6–1.0 mag) and very short period variations during a time-resolved run on 2019 June 12 (BJD 2458646; figure 1). We found that the period is in agreement with the candidate period in Ofek et al. (2020). We also confirmed that the variations recorded for BJD 2458675–2458746, the segment with multiple nightly observations, could be expressed by the same period. By using the entire data BJD 2458646–2458746, we obtained a period of 0.00858995(3) d. The resultant phased light curve (figure 2) shows that that the variations are coherent.

The variation arising from the orbital variation (such as a reflection variable) is very unlikely considering the large amplitude (0.8 mag) and the very short (12.37 min) period. The only known class of binaries with comparably short periods are AM CVn stars (see e.g. Solheim 2010). No known AM CVn stars with similar periods show such large-amplitude orbital modulations. The small parallax of 0.325(119) mas in Gaia Collaboration et al. (2021) also does not favor an underluminous binary.

Stellar pulsations are also unlikely. The large amplitude requires radial pulsations, but there is no known class of radially pulsating variables with this short period.

We propose that this short period may reflect the spin period of the white dwarf. The famous white dwarf pulsar AR Sco (Marsh et al., 2016), which is a 3.56-hr binary consisting of a white dwarf and an M5 star. The spin period of the white dwarf in AR Sco is 1.97 min and amplitudes of the pulses reach 0.5–1.0 mag in the optical (Marsh et al. 2016; Stiller et al. 2018).

[1] 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>.

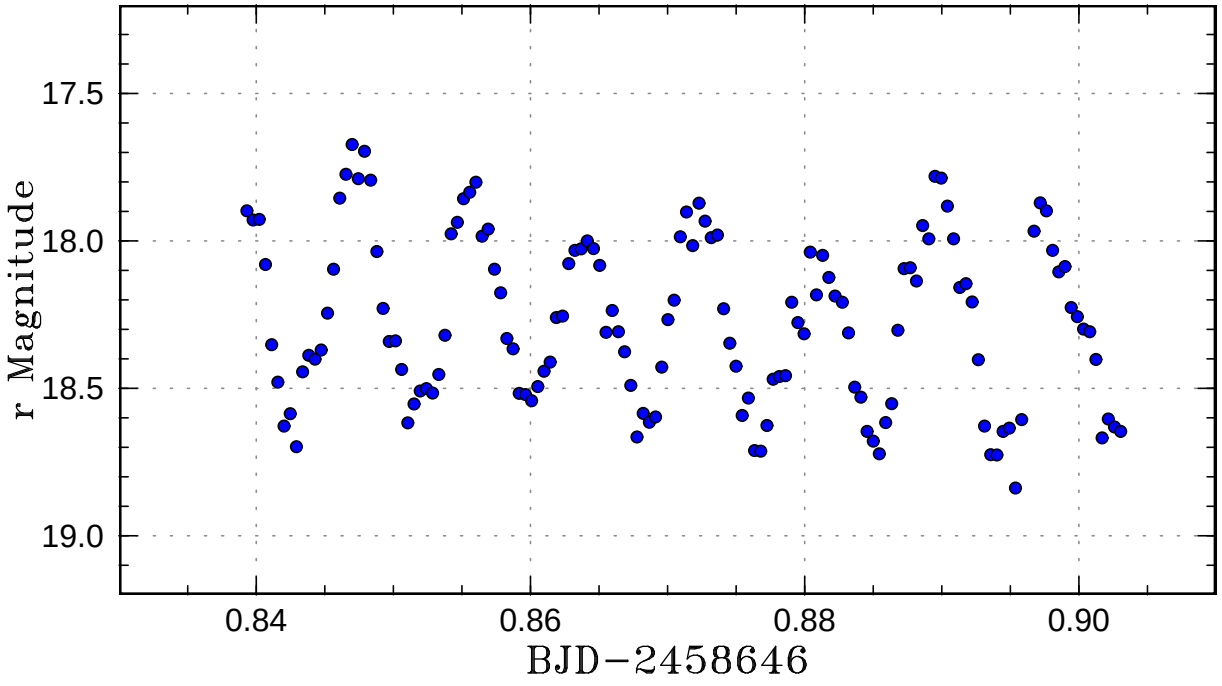

Figure 1: Short-period variation in ZTF J185139.81+171430.3 = ZTF18abnbzvx.

In contrast to AR Sco, orbital modulations are not apparent in ZTF J1851 (figure 3). There were possible outbursts with amplitudes of ∼2 mag such as on BJD 2458685 and on BJD 2459042. The reality of these possible outbursts requires confirmation since there were only a few observations during these events A quasi-simultaneous rise in g and r was recorded on BJD 2459042. The object returned to the normal brightness on the subsequent day. These "outbursts", if present, should have been short-lived as in outbursts in intermediate polars. Although further observations are needed to see whether the short-period coherent variations in ZTF J1851 indeed arises from a spinning white dwarf, this object would be a good candidate for a white dwarf pulsar and should deserve attention.

Acknowledgments

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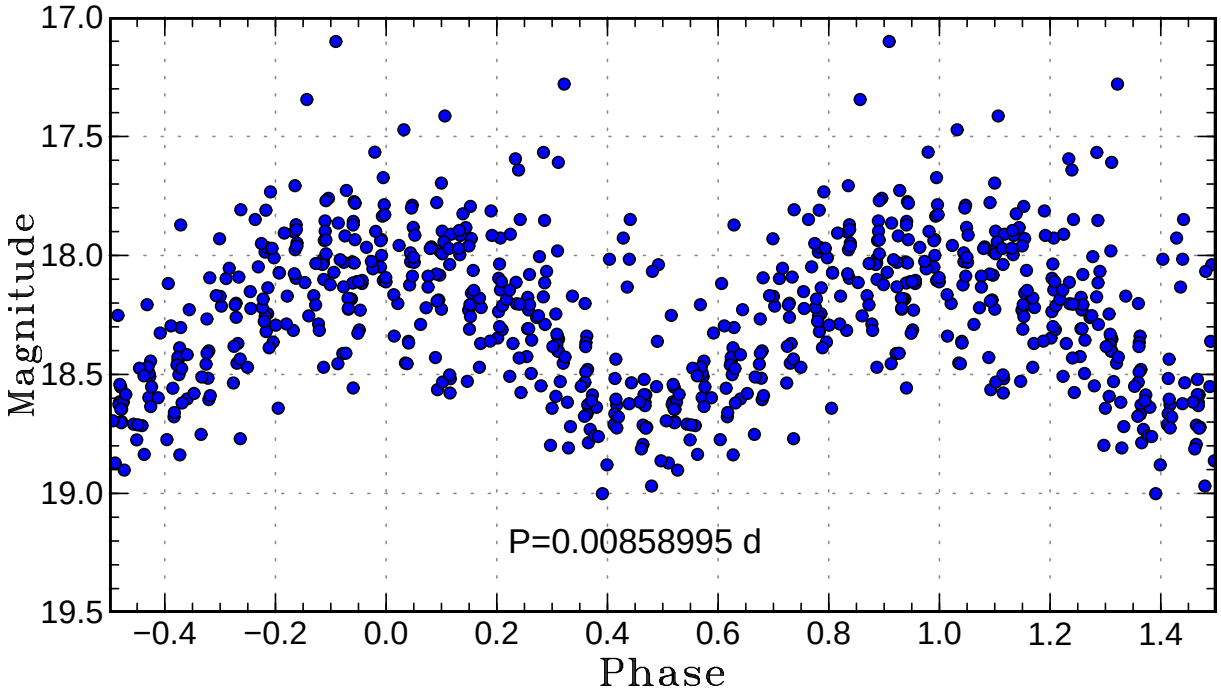

Figure 2: ZTF r phase-folded light curve of ZTF J185139.81+171430.3 = ZTF18abnbzvx for the segment BJD 2458675–2458746. The epoch was chosen as BJD 2458737.3078.

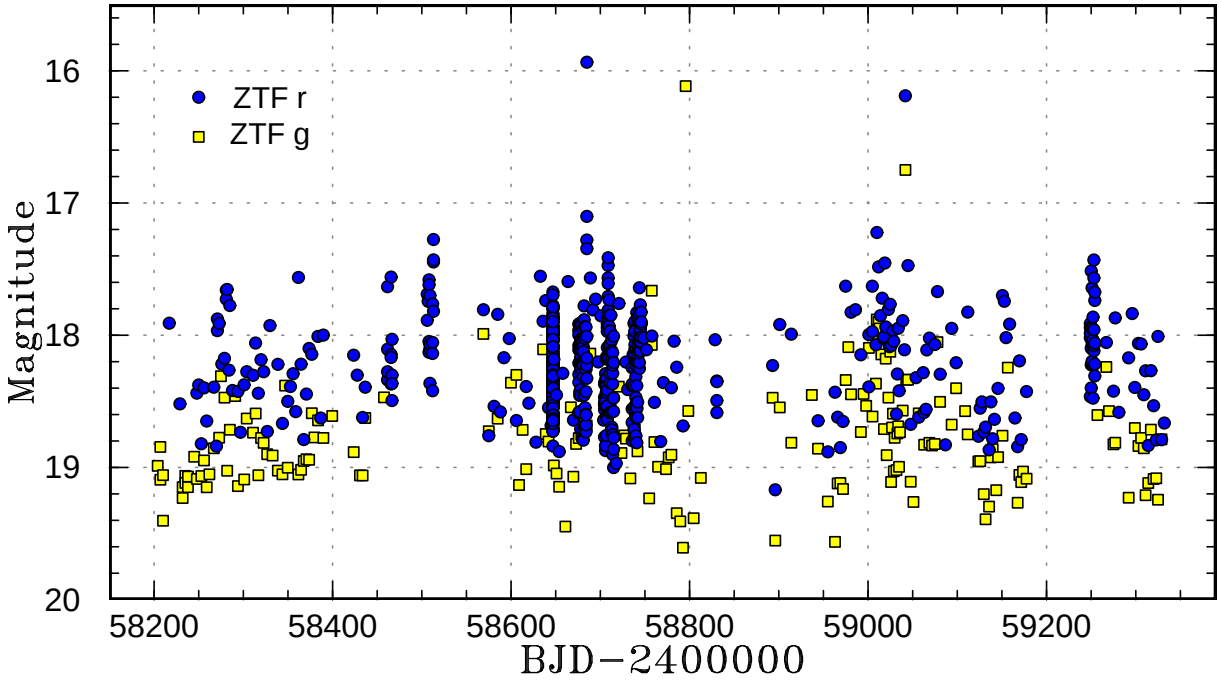

Figure 3: Long-term light curve of ZTF J185139.81+171430.3 = ZTF18abnbzvx from ZTF observations.

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