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USNO-B1.0 0992-0344981, a New Double-mode Type-II Cepheid

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I present a detection of a new double-mode type II Cepheid (BL Her type), USNO-B1.0 0992-0344981, pulsating in the fundamental and first-overtone modes. It is the fifth case in the Galaxy of stars of this type. For the analysis, I used all observations available for the star in the ASAS-SN, ASAS-3, NSVS, and ZTF online public archives. Light elements and parameters of the light curves were obtained.

1 Introduction

Recently, the OGLE group identified a new group of double-mode type-II Cepheids in our Galaxy. First, Smolec et al. (2018) detected two BL Her-type Cepheids, pulsating in the fundamental and first-overtone modes, OGLE-BLG-T2CEP-209 ($P = 1\overset{d}{.}181$, $P_1/P_0 = 0.7051$) and OGLE-BLG-T2CEP-0749 ($P = 1\overset{d}{.}042$, $P_1/P_0 = 0.7051$). Two more stars of this type were later discovered by Udalski et al. (2018): OGLE-GD-T2CEP-0045 ($P = 1\overset{d}{.}086$, $P_1/P_0 = 0.7033$) and OGLE-BLG-T2CEP-1041 ($P = 1\overset{d}{.}257$, $P_1/P_0 = 0.7047$). For one of these stars, OGLE-BLG-T2CEP-209 = V5864 Sgr, the first correct interpretation of its multiperiodicity as a variable with the fundamental and first-overtone oscillations was gives by the author (Khruslov, 2015). Previously, the star was classified by Soszyński et al. (2011) as a BL Her variable star with the primary period $1\overset{d}{.}1812838$ and three additional periods, $0\overset{d}{.}83298$, $0\overset{d}{.}48851$, $0\overset{d}{.}34559$. Khruslov (2015) interpreted the oscillations (besides the two main ones) as interaction frequencies and detected 10 interaction frequencies in his analysis of the OGLE data. However, the variable was re-classified as a Classical Cepheid without sufficient justification.

According to the AAVSO VSX database[1], these four cases are currently all the known variables of this type. The VSX classified the stars as CWB(B) type variables.

In this paper, I present a detection of a new double-mode type II (BL Her type) Cepheid pulsating in the fundamental and first-overtone modes, USNO-B1.0 0992-0344981.

For my analysis, I used all observations available for the star in the following online public photometric archives: the All-Sky Automated Survey for Supernovae (ASAS-SN[2]; Shappee et al., 2014; Kochanek et al., 2017); the All Sky Automated Survey (ASAS-3[3]; Pojmanski, 2002), the Northern Sky Variability Survey (NSVS[4], Woźniak et al., 2004);

[1]https://www.aavso.org/vsx/index.php?view=search.top
[2]https://asas-sn.osu.edu/variables
[3]http://www.astrouw.edu.pl/asas/?page=aasc
[4]https://skydot.lanl.gov/nsvs/nsvs.php

and the Zwicky Transient Facility Catalog of Periodic Variable Stars (ZTF[5]; Chen et al., 2020).

The star was identified in the USNO-B1.0 (Monet et al., 2003) catalog. The coordinates of the variable were drawn from the Gaia DR2 catalog (Gaia Collaboration, Brown et al., 2018). The photometric data used in my study are available online in the html version of this paper as a zip-archive. Figure 1 presents the finding chart of USNO-B1.0 0992-0344981.

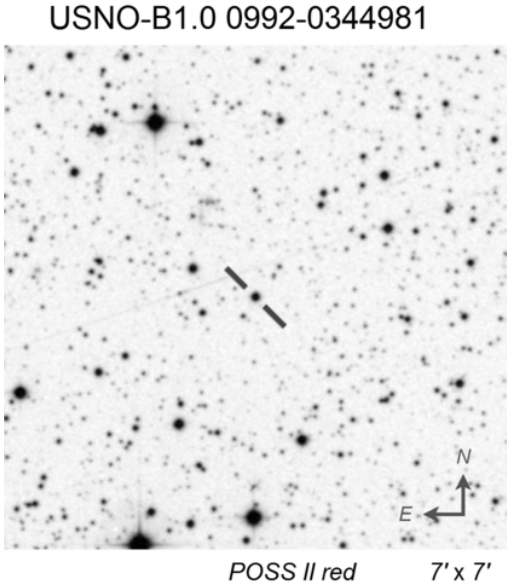

Figure 1. The finding chart of USNO-B1.0 0992-0344981.

2 Variability

The variability of USNO-B1.0 0992-0344981, RA(J2000) = $18^{h}19^{m}32^{s}.39$, Dec(J2000) = $+09^{\circ}17'37''.5$, was announced in the ASAS-SN Catalog of Variable Stars (Jayasinghe et al., 2018). The star was designated as ASASSN-V J181932.39+091737.5. The variable was classified as a BL Her-type Cepheid, type CWB (the variability type according to the GCVS classifications system, Samus et al., 2017). The light elements are: HJD(max)= $2457447.10435 + 1^{d}.1154735 \times E$; the mean magnitude is $13^{m}.73$; and the amplitude is 0.63 in Johnson's V band. The AAVSO VSX gives different light elements: HJD(max)= $2457505.002 + 1^{d}.115483 \times E$, with the reference to the same publication.

I noticed a strong scattering of the phased light curve and suspected multi-periodicity. I analyzed all the observations using Deeming's method (Deeming, 1975) implemented in the WinEfk[6] code written by V.P. Goranskij. Two components of the star's variability were detected using ASAS-SN, ASAS-3, NSVS, and ZTF data.

Power spectra of the variable according to all analyzed data, for the raw data and after subtraction of the fundamental-mode oscillation, are shown in Fig. 2. In all the panels, the structure of the power spectra shows that the secondary periods are real.

[5]http://variables.cn:88/ztf/
[6]http://www.vgoranskij.net/software/

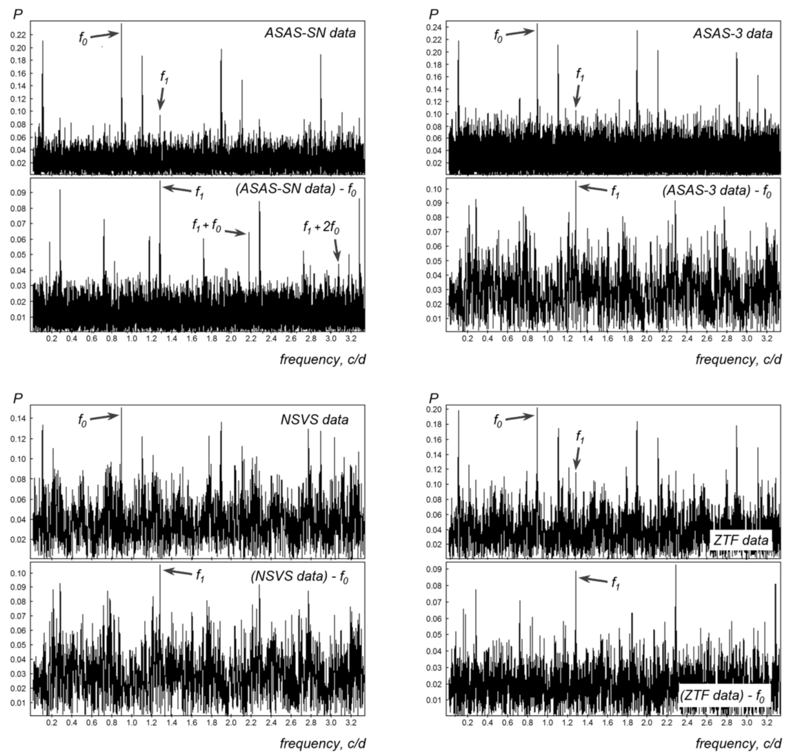

Figure 2. The power spectra of USNO-B1.0 0992-0344981 according to ASAS-SN, ASAS-3, NSVS, and ZTF data.

Table 1. Light elements and oscillation semi-amplitudes of USNO-B1.0 0992-0344981

Mode	Period, days	Epoch, HJD	Semi-amplitude, mag
f_0	1.11543	2457800.70	0.259
f_1	0.77946	2457800.38	0.098
$f_1 + f_0$	0.45885	2457800.445	0.073
$f_1 + 2f_0$	0.32511	2457800.185	0.040
$f_1 - f_0$	2.588	2457801.15	0.032

Our study shows that the variable is pulsating in the fundamental and first-overtone modes. USNO-B1.0 0992-0344981 is a double-mode BL Her-type Cepheid, type CWB(B). In addition to the two main modes, I detected three interaction frequencies: $f_1 + f_0$, $f_1 + 2f_0$, and $f_1 - f_0$.

Table 1 presents the light elements of all oscillations (the period and epoch of maximus) and semi-amplitudes of the oscillations according to ASAS-SN data. To improve the light elements of fundamental and first-overtone oscillations, ASAS-3 and NSVS data were used.

The period ratio, $P_1/P_0 = 0.6988$, is close to 0.7, which is typical for pulsations in the fundamental and first-overtone modes (Petersen, 1973).

The color indices are: $J - K = 0.27$ (2MASS; Skrutskie et al., 2006); $B - V = 0.70$ (APASS[7]). The range of variability is $13\overset{\text{m}}{.}26 - 14\overset{\text{m}}{.}17$ in the V band. We found the asymmetry parameters to be $M - m = 0\overset{\text{P}}{.}31$ for the fundamental mode, $M - m = 0\overset{\text{P}}{.}50$

[7] https://www.aavso.org/download-apass-data

for the first-overtone mode. The light curves of USNO-B1.0 0992-0344981 according to ASAS-SN data are displayed in Fig. 3.

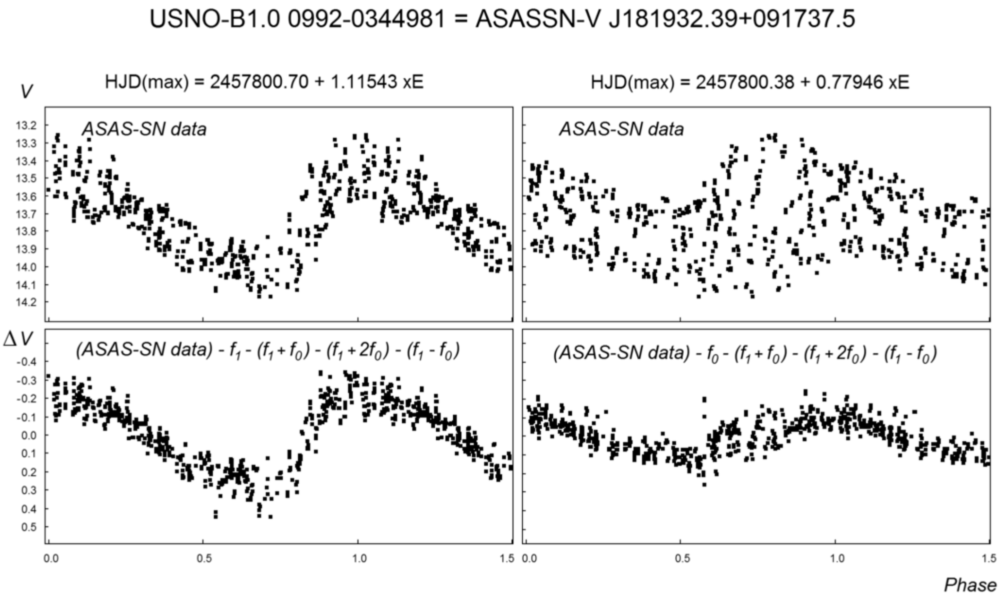

Figure 3. The light curves of USNO-B1.0 0992-0344981 according to ASAS-SN data.

3 Discussion

Udalski et al. (2018) noted that, in the Petersen diagram, the group of double-mode BL Her stars is located out of the sequence of fundamental and first-overtone multi-mode classical Cepheids (it is substantially below them). This group is characterized by the following parameters: the fundamental pulsation periods are close to one day and the period ratio, P_1/P_0, is close to 0.70. The parameters of the known OGLE CWB(B) stars are: $1.04 < P_0 < 1.26$; $0.7033 < P_1/P_0 < 0.7051$; the absolute value of the Galactic latitude (b) does not exceed $4\overset{\circ}{.}8$.

The fundamental period of USNO-B1.0 0992-0344981 is within this interval. The period ratio is close to that for known CWB(B) variables, however it is slightly smaller, additionally increasing the distance of the star from the F/1O Cepheid sequence in the Petersen diagram. USNO-B1.0 0992-0344981 is located at a larger distance from the Galactic plane compared to other known CWB(B) stars of OGLE, its galactic latitude is $+11\overset{\circ}{.}3$, which makes it more reasonable to suggest that the variable is in the Galactic halo as a representative of population II Cepheids of the BL Her type.

USNO-B1.0 0992-0344981 increases the sample of known double-mode type II Cepheid stars to five.

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