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Unusual Short-period Cepheid with a Prominent Bump

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I report my discovery of a peculiar short-period Type II Cepheid in Centaurus. The new variable is pulsating with the period of $2\overset{d}{.}918$, yet it is showing a distinctly double-peaked light curve with two nearly equal maxima. The "bumps" are normally observed in long-period Cepheids with periods ranging from 6 to 16 days, but there are exceptions for stars with shorter P values. The new variable resides in the halo, more than 3 kpc above the Galactic plane, and belongs to population II Cepheids of the BL Her type (CWB).

1 Discovery

The new variable in Centaurus, DDE 109 (GSC 07779–02075; $12^h46^m06\overset{s}{.}50$, $-42°38'05\overset{''}{.}9$, J2000, UCAC4), was found by the author during his routine search for variability in online catalogues. The innovative method is based on identifying variable stars from APASS data release (Henden et al. 2015) using VizieR TAP service at http://tapvizier.u-strasbg.fr/adql/. The method has proved to be effective, resulting in the discovery of twenty new high-amplitude delta Scuti (HADS) stars, eight cataclysmic variables, and two eclipsing subdwarfs listed at the web site http://scan.sai.msu.ru/~denis/VarDDE.html, as well as of several hundred pulsating and eclipsing stars that will be reported elsewhere. The variable discussed in this paper deserves special attention because it stands out among others by its unusual light curve.

I suspected DDE 109 to be variable from its APASS magnitude errors ($V = 14.379 \pm 0.411$, $B = 14.835 \pm 0.566$). Checking the Catalina Real-Time Transient Survey data (Drake et al. 2009) at CRTS website (http://nesssi.cacr.caltech.edu/DataRelease/) immediately confirmed variability with an amplitude of about $0\overset{m}{.}8$ in the "white" light (magnitude range $\sim$ 13.7 to 14.5). The object named SSS_J124606.5-423805 was observed by the Siding Spring Survey telescope on 67 nights from July, 2005 to May, 2013 with a total of 263 data points.

Figure 1 presents the red-light finding chart of the new variable DDE 109.

2 Period Determination

The times of observations were converted from JD to Barycentric Julian Dates using the online period search service http://scan.sai.msu.ru/lk/ by Kirill Sokolovsky. The best value of the period, $2\overset{d}{.}918086(80)$, was obtained using both the Lafler–Kinman and Deeming methods. The phased light curve from CRTS data is presented in Fig. 2. It is characterized by two peaks of nearly the same height – the first one at $13\overset{m}{.}78$ and the

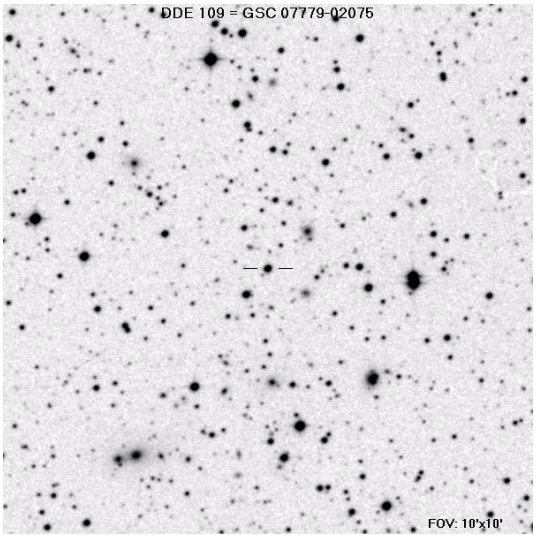

Figure 1.
The finding chart of DDE 109 from the DSS red plate. The field of view is $10' \times 10'$. North is up, east is to the left.

second one at $13\overset{\mathrm{m}}{.}74$. We consider the second (brighter) peak as the maximum and the first (lower) peak as the "bump". Under this assumption, the pre-maximum bump is at phase 0.82 and the local minimum ($13\overset{\mathrm{m}}{.}85$ CV), at phase 0.90. One should also mention the "shoulder" on the descending branch (phases 0.2–0.4).

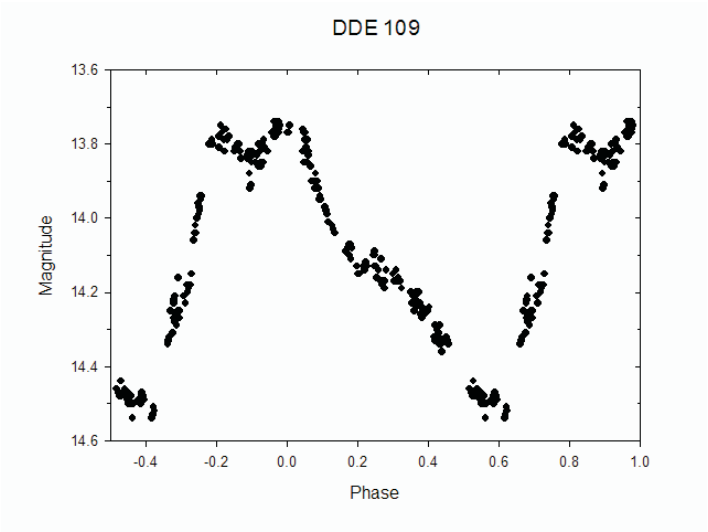

Figure 2.
The light curve of DDE 109 from CRTS data folded with the best pulsation period $P = 2\overset{\mathrm{d}}{.}918086$ and the initial epoch $T_0 = 2453876.112$ (HJD).

The light elements of DDE 109 obtained from CRTS data are:

$$\mathrm{Max} = HJD2453876.112 + 2\overset{\mathrm{d}}{.}918086 \times E.$$

3 Identifications in Catalogues

Being brighter than $15^{\rm m}$, the new variable DDE 109 is present in many astrometric and photometric catalogues. Several identifications are listed below, with the corresponding magnitudes.

GSC 07779–02075 ($m_{\rm pg} = 15.00 - 15.31$);
2MASS J12460650–4238059 ($J = 13.15$, $H = 12.85$, $K_s = 12.81$);
GALEX J124606.5-423805 (FUV=N/A, NUV=19.28);
USNO-A2.0 0450-14689472 ($b = 14.4$, $r = 14.1$);
USNO-B1.0 0473-0357256($R1 = 14.41$, $B2 = 15.27$, $R2 = 14.59$, $I = 13.88$);
UCAC4 237-060567 ($m_f = 14.087$).

The $(J - K_s)$ color index is 0.34 ± 0.04. The galactic latitude is $+20°$, with the following extinction values from Schlafly and Finkbeiner (2011): $A_B = 0.328$, $A_V = 0.248$, $A_R = 0.196$, $A_J = 0.064$, $A_K = 0.027$. Assuming the absolute magnitude of DDE 109 to be $M_V = -1$, we obtain the estimate of 10 kpc for the distance and > 3 kpc for the height above the Galactic plane. The object definitely belongs to the halo of Population II stars.

Figure 3 shows the period–color diagram of known CWB variables from the AAVSO VSX database (Watson et al. 2006) that have both J and K_s magnitudes in the 2MASS catalogue. Uncertainties of the $(J - K_s)$ color indices are typically smaller than the symbol size. 98 stars with GCVS names are plotted as gray circles; 69 stars from the OGLE bulge survey, as violet squares; and DDE 109, as the blue diamond. The position of DDE 109 in the diagram nearly coincides with that of the variable BC Aql ($P = 2\overset{\rm d}{.}9053$, $J - K_s = 0.336$). However, the light curve of BC Aql is typical of CWB stars.

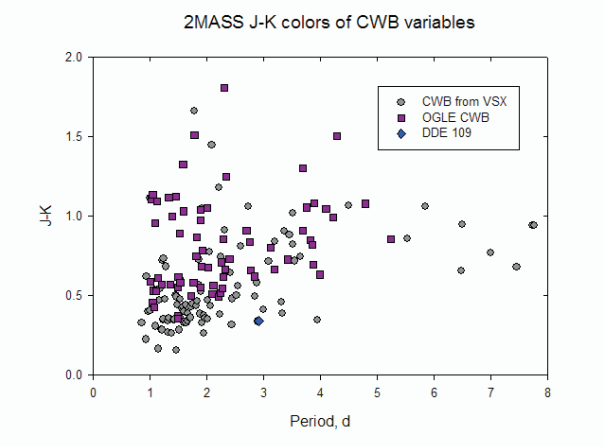

Figure 3.
The $J - K_s$ (2MASS) colors of CWB variables, not corrected for extinction. Stars from OGLE BLG survey are plotted as violet squares; stars with GCVS names, as gray circles; DDE 109, as a blue diamond.

4 Discussion

To our knowledge, no other short-period Cepheid shows a double-peaked light curve with nearly equal maxima. The most remarkable pre-maximum bump is observed for the CWB-type variable V439 Ophiuchi with the period $P = 1\overset{\rm d}{.}893$, nearly 1.5 times shorter than that of DDE 109. The phased light curve of V439 Oph from ASAS-3 data (Pojmanski 2002)

is shown in Fig. 4. Despite the much lower first "bump" ($0^m.3$ below the maximum) and the dip ($0^m.2$ above the minimum), the phases of both peaks, the dip, and the "shoulder" in the case of V439 Oph are very close to those for DDE 109.

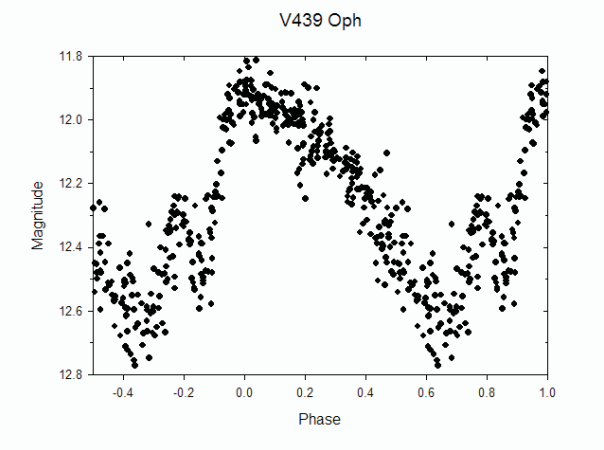

Figure 4.
The light curve of V439 Oph from ASAS-3 data folded with $P = 1^d.893011$.

5 Conclusion

The serendipitous discovery of DDE 109 shows that many remarkable variable stars remain not found despite their large-amplitude variability in publicly available databases and catalogues. The powerful tools of Virtual Observatory (namely, Table Access Protocol service at VizieR) can be effectively used for identifying such objects deserving a further study. Southern celestial hemisphere, including Siding Spring Survey data, should be thoroughly investigated. Multi-color photometry and spectroscopic observations of DDE 109 are strongly encouraged.

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