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An Attempt to Identify Classical Cepheid Candidates in the LAMOST Spectroscopic Survey

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We describe our attempt to find new candidate classical Cepheids and other pulsating variable stars in the LAMOST spectroscopic survey using GAIA eDR3 data and existing photometric archives. Several stars deserve dedicated photometric observations.

1 Introduction

This paper is a by-product of our study aimed at finding double-star candidates from spectra of the LAMOST survey. The main results of the study will be published elsewhere.

LAMOST is a new type of 5-degree-wide-field telescope with a large aperture of 4 m. Its focal plane is covered by 4000 fibers connected to 16 sets of multi-object optical spectrometers. These spectrometers simultaneously obtain a similar number of low-resolution ($R = 1800$) spectra in two wavelength arms, $3700 - 5900$ and $5700 - 9000$ Å. It is installed at the Xinglong observing station (Hebei province, China). An overview of the LAMOST project can be found in Zhao et al. (2006, 2012). Our sub-project was based on the LAMOST DR5 catalog of A, F, G, and K stars (Luo et al., 2019). We cross-matched it with the best astrometric data currently available, those from the Gaia Early Data Release 3 (Gaia eDR3; Gaia Collaboration et al., 2021).

When trying to identify LAMOST spectra with binary-star features, it is desirable to preliminary exclude high-amplitude variable stars. Our initial idea was that recent developments in stellar parallaxes and stellar photometry would permit us to find a certain number of stars in the Cepheid instability strip of the Hertzsprung-Russell diagram, with the hope to identify unknown classical Cepheids. Variable stars of this type are still of great importance for many directions of astrophysical research, including establishing of a reliable distance scale in the Universe. Using existing photometric surveys, such as ASAS-SN or Catalina, we would be able to select the most promising stars and, if necessary, arrange for their new photometric observations.

2 Selection of stars and results

Of 5.1 million of the LAMOST stars cross-matched with the Gaia eDR3, about 10,000 can be related to the location of the Cepheid instability strip. Of them, in the course of our analysis, we selected about 360 Cepheid instability-strip candidates contained in the LAMOST survey and analyzed them using information from the General Catalogue of

Variable Stars (GCVS; Samus et al., 2017), VSX database (Watson et al., 2007), ASAS-3 (Pojmanski, 2002), ASAS-SN (Shapee et al., 2014; Kochanek et al., 2017), Catalina (Drake et al., 2009) photometric surveys.

We represented the position of the Cepheid instability strip with the approximate formula from Tammann et al. (2003):

$$M_V^0 = (-8.58 \pm 0.5)(B - V)_0 + 2.27\,.$$

For transition from $(M_V,\ B-V)$ to Gaia eDR3 $(M_G,\ BP-RP)$, we use color transformations provided by Riello et al. (2021). The location of the instability-strip ridge, in terms of Gaia eDR3 photometry, can be written as:

$$M_G^0 = 2.187 - 6.762(BR - RP)_0 + 2.8945(BP - RP)_0^2 \\ -8.010(BP - RP)_0^3 + 4.155(BP - RP)_0^4 - 0.583(BP - RP)_0^5\,.$$

We obtain absolute magnitudes for LAMOST stars based on Gaia eDR3 parallaxes, and estimate interstellar extinction and reddening for them using Gaia photometry and effective temperatures from LAMOST. The details of the procedure we use for this purpose can be found in Nekrasov et al. (2021).

We did not find any really promising candidate classical Cepheids, with the exception of already known cases: the classical Cepheids ASAS J065642+0835.2, discovered in the ASAS-3 survey; V342 Cas, known for decades; V598 Per (Antipin, 1998); ZTF J041108.41+563210.6 (Chen et al., 2020); the small-amplitude (DCEPS) Cepheid ASASSN-V J051348.97+311429.6, found in the ASAS-SN survey.

The star V465 Oph is called DCEP in the ASAS-SN survey, while it is a CWB star in the GCVS; it is rather far from the galactic plane, and the GCVS classification seems more justified. The star OGLE-GD-CEP-0031 is attributed to DCEP(B) double-mode classical Cepheids in the VSX, but its period ($0\overset{d}{.}31$) seems too short for the type. VSX classification of ASAS J065642+0835.2, following ASAS-3, is DCEP (first overtone) or ACV. The star's spectral type (Simbad) is F0, leaving both possibilities open. The period is $2\overset{d}{.}22$, the amplitude is very small. A special photometric study of the variable can be recommended.

In the International Variable Star Index, the star VSX J133234.9+061339 (spectral type G5) is an RV Tau variable with the period of 198^{d}. The ASAS-SN data base, despite the VSX classification being known to its compilers, lists the variable as an SR star with P about $99\overset{d}{.}0$. Figure 1 shows a fragment of the star's light curve from ASAS-SN V-band data, showing that, indeed, the star sometimes reveals RV Tauri behavior with alternating deep and shallow minima, while other time intervals permit us to prefer the SR solution with a twice shorter period. At any rate, this is a star close to the Cepheid instability strip, but, again, far from the galactic plane and definitely not a classical Cepheid. It would be interesting to perform a multicolor photometric study of this variable in order to check if the behavior of its color indices corresponds to patterns known for RV Tauri stars or not.

Similar cases are NSVS 7300878 (ASASSN-V J075151.02+251848.2), an SRD star with $P = 100\overset{d}{.}4$ in the VSX database; CSS J042001.7+171645, CWA with $P = 16\overset{d}{.}64$ in VSX; ASAS J213445-0546.8 ($P = 107\overset{d}{.}9$). They are also close to the instability strip and far from the galactic plane. ASASSN-V J213205.93+404103.1 is close to the galactic plane, it is a faint semiregular variable with a period of 100^{d}. In our Galaxy, we do not know classical Cepheids with periods that long. The star deserves a dedicated photometric study.

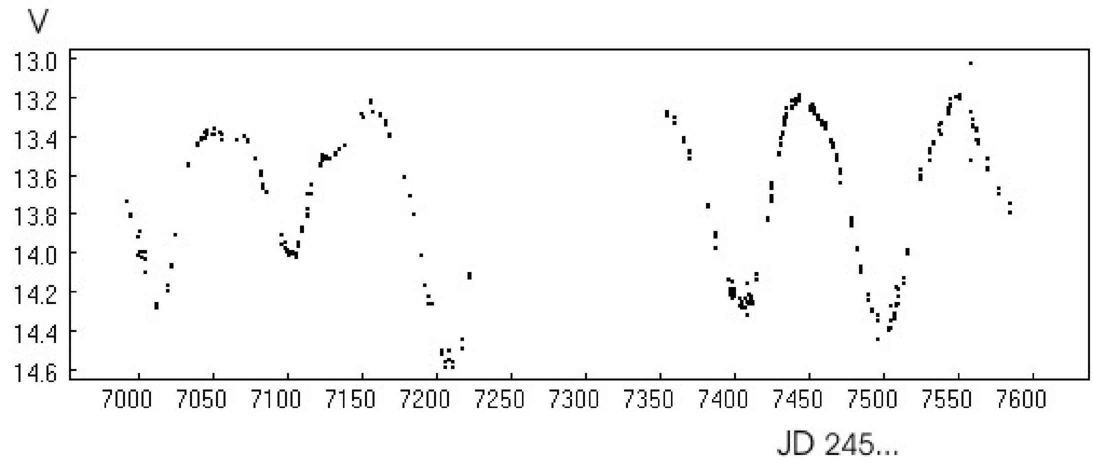

Figure 1. A fragment of the light curve of VSX J133234.9+061339, from ASAS-SN data.

Our lists contain many eclipsing variables (usually they are most numerous variable stars in any sky field large enough and, if close to the main sequence, can happen also in the formal instability strip). RR Lyrae stars (also Cepheid instability-strip objects, but at a later evolution stage compared to classical Cepheids, with lower masses and lower luminosities), δ Scuti variables (close to the intersection of the instability strip with the main sequence), stars of other types are also represented.

3 Conclusions

Our attempt to find new classical Cepheids on the base of the LAMOST spectroscopic survey and Gaia eDR3 data has not been successful. Several stars, for example, ASAS J065642+0835.2, VSX J133234.9+061339, ASASSN-V J213205.93+404103.1 can be recommended for further photometric investigations.

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