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CzeV293 and CzeV581—Two new high-amplitude double-mode delta Scuti stars

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HIGHLIGHTS

- Discovery of two new high-amplitude delta Scuti stars is presented.
- Frequency analysis showed that both stars are double-mode pulsators.
- Absolute magnitude, intrinsic colour index and temperature are estimated.

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ABSTRACT

We report on the discovery of two high-amplitude double-mode delta Scuti stars in constellations of Hercules and Auriga. The stars were observed photometrically in five and two seasons, respectively. Frequency analysis revealed that both stars show complex pulsation behaviour with two independent modes and several combination peaks. Placing the stars into the Petersen diagram allowed us to identify the pulsation modes as the fundamental and the first overtone. Both stars follow the general trend for F/1O pulsators in the short-period part of the Petersen diagram and turned out to be classical members of HADS group of variables. Using empirical formulae we roughly estimate visual absolute magnitude, intrinsic $(B-V)_0$ colour index and temperature of the target stars.

1. Introduction

The δ Sct stars are Population I A- to F-type main sequence (or slightly off-main-sequence evolved) stars residing the lower-part of the classical Cepheid instability strip. With masses between 1.2 and 2.5 $\mathfrak{M}_\odot$ they are slightly more luminous and larger than our Sun. The class of δ Sct is usually defined by periods between 18 min and 8 h and amplitudes of light changes between less than 10^{-3} and 1 magnitude. More details can be found in the reviews by Breger (2000) and Rodríguez et al. (2000).

A very small fraction of all δ Sct stars (about 1%, Lee et al., 2008) have amplitudes larger than 0.3 mag. These stars, located in a very narrow central region of the instability strip, are called high-amplitude δ Sct stars (HADS). The pulsations are excited by κ-mechanism similarly as in Cepheids and RR Lyrae stars. Also the light-curve shape is similar to these pulsating stars. This is the reason that HADS were called dwarf Cepheids in the past.

In contrast to low-amplitude δ Sct stars, which pulsate mainly non-radially, HADS are considered to pulsate in low-order radial modes, usually in the fundamental and the first overtone. About $\sim$ 40% of HADS are double pulsators showing simultaneous pulsations in the fundamental (F) and the first overtone mode (1O) with amplitudes higher for F mode predominantly (McNamara, 2000a). However, also non-radial pulsations were discovered in HADS with a precise data (Poretti, 2003; Pietrukowicz et al., 2013).

In this paper we deal with two new double-mode HADS CzeV293 and CzeV581 in constellations of Hercules and Auriga. In Section 2 we give basic information about observation and data reduction, in Section 3 we aim to give an impression about analysis of the data and identification of the pulsation modes. Based on empirical calibrations we estimate basic physical parameters of the two stars in Section 4. Finally, the summary is given in Section 5.

2. Observation and data reduction

The stars were discovered during searching for new variables in fields in Hercules (near V1134 Her) and Auriga (near MR Aur)constellations in 2011 and 2014. The designation CzeV293 and CzeV581 comes from the catalogue of variable stars discovered

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Table 1
Basic information about studied stars, their comparison stars and journal of observation. Coordinates, magnitudes and cross-identification comes from the UCAC4 catalogue (Zacharias et al., 2013). The last column 'TS' shows time span of the data.

ID UCAC4	RA(2000)	DE(2000)	V [mag]	$B-V$ [mag]	Nights	Points	TS (d)
			CzeV293				
512-075014	18 28 54.893	+12 21 24.41	15.673	0.41	37	2483	1435.1
Comparison star							
511-077030	18 28 42.934	+12 08 06.62	13.085	0.607			
			CzeV581				
606-023651	05 46 27.210	+31 11 09.91	15.353	0.719	24	1836	390.2
Comparison star							
605-024710	05 46 33.702	+30 54 52.75	12.680	0.466			

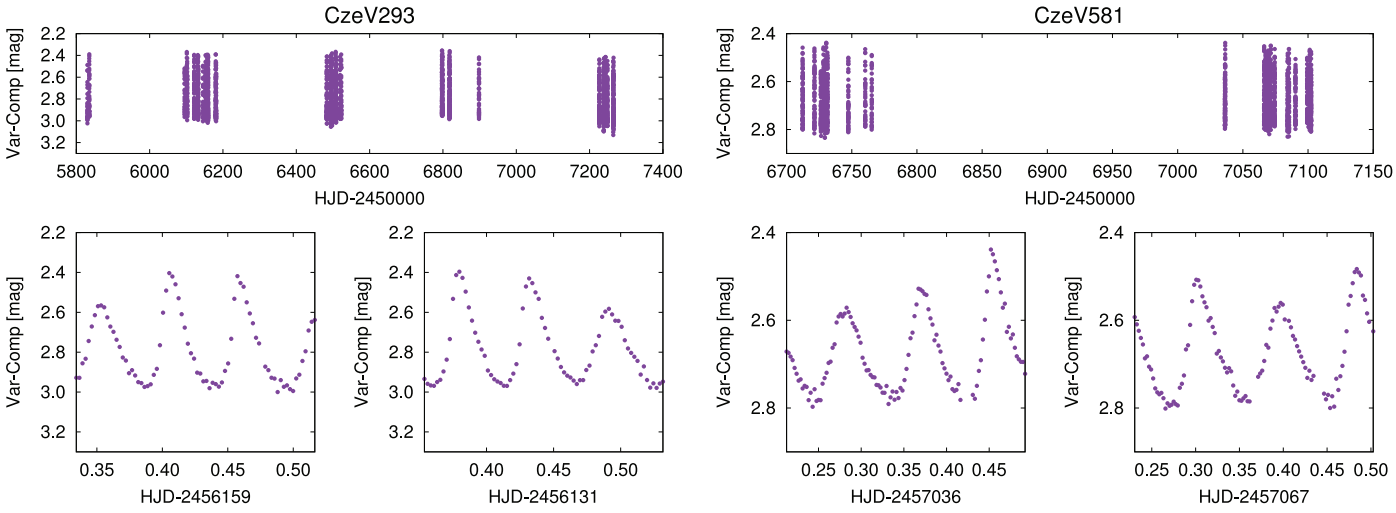

Fig. 1. Distribution of the data (the top panels) and examples of light curves showing behaviour during single nights.

by Czech astronomers[1](Brat, 2006). The cross identifications, positions, magnitudes, and information about the length of the observation, number of nights and a total number of points gathered are in Table 1.

The fields were observed regularly using a 10 in. f/5.4 Newtonian telescope equipped with a G4-16000 CCD camera[2] at BSObservatory Zlin, Czech Republic. During five and two seasons almost 2500 and more than 1800 measurements were obtained for CzeV293 and CzeV581, respectively. The observations were performed using no photometric filter to maximize the throughput and 180 s exposure were integrated to detect faint stars. The data reduction and aperture photometry was performed using C-Munipack software[3]. Characteristics of comparison stars can be found in Table 1. The relative precision of individual differential-photometry data point is about 0.025 mag (CzeV293) and 0.015 mag (CzeV581) in average.

The distribution of the data (the top panels of Fig. 1) is very heterogeneous with large gaps caused by observational constraints of the targets. Different heights and shapes of the light curves shown in the examples in the bottom parts of Fig. 1 suggest that both stars undergo complex pulsations with more than a single period.

The shape of the light curves strongly resembles light variations of RRab Lyrae stars. Colour indices from the APASS photometry (Henden et al., 2009) point to the temperatures around 7000 K which lies in the δ Sct, but also in RR Lyrae domain. Also the amplitudes of about 0.6 and 0.4 mag for CzeV293 and CzeV581 are well within the limits for both RR Lyrae stars and HADS. However, the ability of recording three cycles during a single night suggests a very short period which is far below the RR Lyrae range. Therefore we classify both variable stars as HADS.

3. Frequency analysis and mode identification

We searched for the periodicity in the data using publicly available software Period04 (Lenz and Breger, 2005). This software employs discrete Fourier method for transformation from the time to frequency domain and non-linear least-squares fitting method for estimation of the parameters of the final sine-series fit.

We iteratively searched for the peaks with the highest amplitude and prewhitened the spectra till no peak has signal-to-noise ratio $S/N > 4$. In each step the parameters of the fit were improved using built-in tool 'Improve all'. Because the periods of δ Sct stars can be very short, we searched for the peaks in frequency interval from 0 to 100 c/d. This is well below the Nyquist frequency which is higher than 200 c/d for our data. The prewhitening sequences are shown from top to bottom in Fig. 2. In CzeV293 we removed suspicious long-term trend apparent from the top left panel of Fig. 1 applying sine fit with period of about 827 d. Because there is no evidence that this change is real we suppose that it is of artificial nature. For a better analysis of this behaviour more extended data set is needed.

From the distribution of observations strong aliasing can be expected to dominate in the frequency spectra. Especially daily, and to less extend also yearly, aliases are very pronounced (see the top

[1] http://var2.astro.cz/czev.php.
[2] http://www.gxccd.com/.
[3] http://c-munipack.sourceforge.net/.