Variability of HADS stars in TESS

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The TESS satellite provides superb-quality light curves for many variable stars. Among them there are high-amplitude δ Scuti stars (HADS) which pulsate mainly in radial modes with periods of the order of 1–3 hours. I will present the results of the analysis of TESS light curves for a sample of about 30 HADS stars from sectors 1–4. The pulsational behaviour of the sample will be characterized by means of the parameters of the Fourier decomposition and period ratios (Petersen diagram). The occurrence of non-radial modes and high radial overtones in HADS stars will be also discussed.

1 Introduction

High-amplitude δ Scuti (HADS) stars and SX Phoenicis stars are two groups of large-amplitude pulsating stars located at the intersection of the classical instability strip and main sequence (MS). While HADS stars are MS or early post-MS stars, SX Phe stars are believed to be more advanced in evolution and the products of stellar mergers. The differences in their stellar structure may be reflected in the pulsations they show, both in the shapes of the light curves and in frequency content. A detailed investigation of these dependencies was not previously possible due to the lack of good-quality light curves for a large sample of stars. This can change with the TESS mission, which provides excellent-quality data for a large number of HADS and SX Phe stars. As part of the project aimed at characterization of pulsations in these stars, we proposed 213 HADS and SX Phe stars for 2-min cadence observations with TESS. The stars were selected from the literature and from analysis of the ASAS-3 data (Pojmański, 2001) by Pigulski & Kotysz (in preparation). The present poster shows preliminary results for a sample of 29 HADS and SX Phe stars located in the first four sectors observed by TESS. Of the 29 stars in our sample, six had no 2-min cadence photometry. For these stars, we performed 30-min cadence photometry with the full frame images by means of our own software. The photometric data were subsequently analyzed using a standard prewhitening. At each step of this procedure we identified possible harmonics and combination frequencies.

2 Results of the analysis

In the sample of 29 HADS stars we analyzed, we found different types of behaviour including: (i) single-mode pulsations with no terms other than harmonics detected. (ii) Double-mode pulsations with two modes with a period ratio in the range 0.76 – 0.78, characteristic of two radial modes, fundamental (F) and first overtone (1O). As can be seen in Fig. 1, seven stars perfectly follow the sequence for F/1O stars. (iii) single or high-amplitude double-mode pulsators in which additional modes, likely non-radial were also observed. An example of such a star is shown in Fig. 2. A few stars showed also low-frequency terms, which can be interpreted as likely g modes.

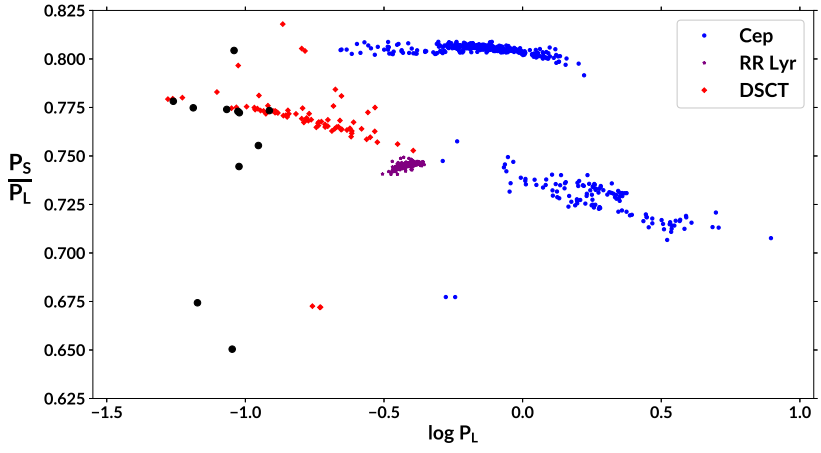

Fig. 1: Petersen diagram for classical Cepheids (blue), RR Lyrae (violet) and HADS stars (red). Twelve stars with period ratios in the range 0.625–0.825 from our sample are shown as black dots. The data for background stars were taken from OGLE catalogues of stars in Magellanic Clouds (Poleski et al., 2010; Soszyński et al., 2008, 2010b, 2009, 2010a).

The shapes of the light curves of HADS and SX Phe stars can be also studied by means of Fourier decomposition. Some coefficients calculated from this decomposition are presented in Fig. 3. As can be seen, all but two stars from our sample fall into the area covered by HADS stars. The remaining two are RR Lyrae stars, mistakenly included in the list of possible δ Sct stars. The two groups of RR Lyrae stars are RRc (left) and RRab (right), that is, 1O and F pulsators, respectively.

3 Non-radial modes

An example of a HADS star showing non-radial modes, ASAS 032246-7237.8 = TIC 431589510, is shown in Fig. 2. In addition to the main frequency $f_1 = 8.1919\ \mathrm{d}^{-1}$ and its eight lowest harmonics, we detect at least three non-radial modes, all with much smaller amplitudes, below 0.6 ppt in comparison to 81.7 ppt for f_1. A combination of f_1 and one of non-radial modes can also be seen.

4 Conclusions

TESS data with their superb quality allow for detailed investigation of HADS and SX Phe stars, in particular the shapes of their light curves. Data from 13 sectors of TESS satellite are now available. The final sample we are going to analyze will likely include about 300 HADS and SX Phe stars. In combination with spectroscopy (which we have already obtained for over 70 targets), we will be able to check if and how the shapes of the light curves of HADS and SX Phe stars depend on stellar parameters (mass, radius, metallicity, age, etc.). This may help to find in which circumstances radial modes dominate the frequency spectra in both types of pulsating stars.

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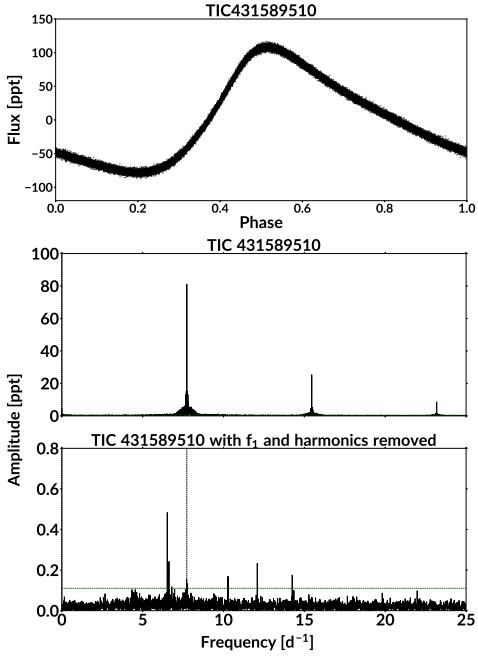

Fig. 2: Top: data phased with the dominant pulsation period of 0.12207 d. Middle: Frequency spectrum of the original data. The frequency f_1 and its two harmonics can be seen. Bottom: Frequency spectrum of data prewhitened with f_1 and its eight harmonics. The peaks correspond to non-radial modes and the combination of f_1 and one of non-radial modes.

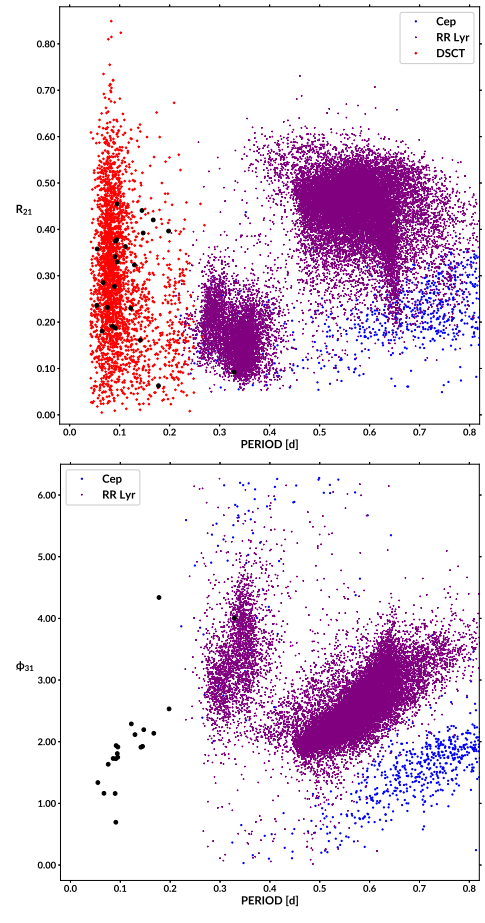

Fig. 3: Top panel: Fourier parameter R_{21} plotted as a function of period. Symbols are the same as in Fig.1. Bottom panel: Fourier parameter ϕ_{31} plotted as a function of period. Symbols are the same as in Fig.1.

References

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