Abstract

RR Lyrae stars and classical Cepheids are pulsating stars located in the classical instability strip in the Hertzsprung-Russel diagram. They are essential astrophysical tools for studying distances, Galactic structure, and stellar populations. With only a few exceptions, these stars were not studied extensively with asteroseismic methods, because their pulsations are typically in one or two modes. Discoveries from recent years showed that additional non-radial modes might be detected in these stars, giving a chance to use asteroseismic techniques on these objects.

δ Scuti stars are pulsating stars located at the intersection of the classical instability strip with the main sequence. They are a diverse group of pulsators with different masses, populations, and at different evolutionary stages. The majority of δ Scuti stars are low-amplitude multi-mode non-radial pulsators, which makes them difficult targets for asteroseismic studies since the mode identification is not straightforward. However, two subgroups of High-Amplitude Delta Scuti stars (HADS) and SX Phoenicis stars have pulsation characteristics similar to RR Lyrae stars and Cepheids, with dominant radial pulsations. Multi-mode radially pulsating HADS and SX Phe stars allows for mode identification through period ratios and application of asteroseismic methods to study these stars.

The main goal of this thesis is to study for the first time classical pulsators and HADS with asteroseismic methods on a large number of objects. This study consists of an observational part in which I studied the photometric time series, with the goal of finding suitable candidates for asteroseismic modeling, and a theoretical part, which involves asteroseismic modeling of the multi-mode stars I have found.

In the first part of the thesis, I focused on detecting and analyzing the additional non-radial modes present in RR Lyrae stars. The most characteristic additional signal in these stars is the so-called 0.61-mode, forming a period ratio with the first-overtone of approx. $0.60 - 0.65$. The largest census of RR Lyrae stars with the additional signal up to date is presented in Sec. 2 of the thesis. This analysis resulted in the discovery of 95 per cent of currently known RR Lyrae stars with this signal. With almost a thousand such stars detected, I could present the statistically significant analysis of the pulsation characteristics and test the current hypothesis explaining the origin of this signal. Additionally, I present a discovery of other additional signals in RR Lyrae stars, that are currently not understood.

The current model explaining this additional signal involves excitation of non-radial modes of moderate degrees (8 and 9 in RR Lyrae stars or 7, 8, and 9 in classical Cepheids). If these non-radial modes could be detected in spectroscopic data, then spectroscopic mode identification techniques could be used for a direct confirmation of the proposed model. In the Sec. 3 of the thesis, I performed a feasibility study on whether those non-radial modes of moderate degrees can be detected in spectroscopic data for classical Cepheids.

In Sec. 4 asteroseismic methods were used to determine the physical parameters of RR Lyrae stars with additional non-radial modes, assuming that the model identyfing these periodicities as modes of degrees 8 and 9 is correct. Based on the census of RR Lyrae stars with these

modes, I used selected triple-mode RR Lyrae stars with non-radial modes, and by theoretical modeling, I inferred their physical parameters. In particular, the mass estimation is essential, since currently there is no confirmed RR Lyrae star in an eclipsing binary system, which makes asteroseismology the only reliable method to measure their masses. The results presented here are important for our understanding of classical pulsators since they were rarely a target of asteroseismic modeling.

The final result presented in the thesis is based on the observational and theoretical investigation of HADS. The observational result, presented in Sec. 5, was based on a sample of δ Scuti stars available in the literature. Using this sample I found candidates for HADS pulsating simultaneously in multiple radial modes. My candidates form the largest such sample known so far. In Sec. 6 I investigated this sample of HADS theoretically to infer their physical parameters. Such analysis resulted in the largest sample of HADS with determined physical parameters and allowed for the selection of candidates for SX Phoenicis stars.