Stars and their variability observed from space
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RESULTS OF THE ENSEMBLE ASTEROSEISMOLOGY OF B-TYPE STARS IN OPEN CLUSTER NGC 6910

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Abstract. We present the results of ensemble asteroseismology of B-type pulsating stars in the NGC 6910 open cluster. Ensemble asteroseismology turns out to be very useful for examination of the instability strip, mode identification and testing the excitation of the modes. It also helps to constrain parameters of the cluster, its age in particular. The outcome shows the large potential of this method, especially when used with space telescopes, e.g. Kepler or TESS, that can provide precise photometry for cluster members.

Keywords: asteroseismology, stars: fundamental parameters, open clusters and associations: individual: NGC 6910

1 Introduction

NGC 6910 is a young open cluster located in the Cygnus constellation. Its age is estimated at 6 ± 2 Myr (Kołaczkowski et al. 2004) and distance of 1.1 - 1.5 kpc (Kharchenko et al. 2005, 2013). The cluster is known as one of the reachest open clusters in β Cep-type pulsating stars (Kołaczkowski et al. 2004; Pigulski 2008; Moździerski et al. 2018), which makes it a very good target for performing the modeling called ensemble asteroseismology. Here we present some results of the ensemble asteroseismology procedure which we developed for hot, pulsating stars in NGC 6910 cluster. Details of the procedure and full results were published by Moździerski et al. (2019).

2 Observations and analysis

Photometric and spectroscopic observations were obtained at 12 observatories, during two campaigns; in the years 2005 – 2007 (11 observatories) and in 2013 (2 observatories). For the purpose of our work, we chose only the longest and best-quality photometric data obtained in three observatories; Białków Observatory, Xinglong Observatory and ORM (Mercator telescope). In total, we obtained about 3800 CCD frames in B, 19 800 in

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V, 5800 in I_C and 1350 CCD frames through U_G filter. The data were collected during 138 observing nights between August 2005 and October 2007 in Białków and Xinglong, and during 116 nights between April 2005 and August 2007 in ORM. Spectroscopic observations were obtained with 2.56-m Nordic Optical Telescope of ORM (the year 2007), 1.93-m telescope of OHP (the year 2007) and APO 3.5-m Astrophysical Research Consortium telescope (the year 2013). Fourier analysis of V-band observations allowed us to detect, in all nine examined B-type pulsating stars (NGC6910-14, -16, -27, -18, -25, -41, -34, -38 and -36), 40 frequencies, of which 37 are intrinsic. We determined atmospheric parameters for all of these stars using our spectroscopy and Strömgren photometry available in the literature. U_G, B, V and I_C photometry was used for photometric identification of modes with the method developed by Daszyńska-Daszkiewicz et al. (2002, 2005). We also made use of the FPF method (Zima 2006) implemented in the FAMIAS package (Zima 2008) for spectroscopic mode identification of the highest amplitude modes in NGC6910-14 and -18.

3 Ensemble asteroseismology and the results

Our method is based on iterative constraining of the cluster age, and assumed coevality of member stars. We defined a grid of parameters for evolutionary and pulsational models and used identified modes to put limits on the cluster age. Then, we derived parameters of the stars and iteratively narrow down these parameters and the cluster age. In parallell, we gained more constraints on mode identification (ensemble identification). As the final result, we determined the age of NGC 6910 as 10.6 ± 0.9 Myr, and we constrained parameters for all nine B-type pulsating stars. Our modeling allowed us to distinguish p, g and mixed modes. It proved that some modes of high frequency are in fact g - modes (in NGC6910-34, -38 and -36). This shows that period alone cannot be always used to distinguish between β Cep and SPB stars. We also found that NGC6910-38 is a β Cep star with unusually low mass, about 5.6 $M_\odot$. This star is decreasing the low-mass boundary of the excited p-modes of B-type stars, compared to the state-of-the-art theoretical predictions (Fig. 1). Our results present promising perspectives for the use of ensemble asteroseismology when many modes are detected for many stars. Such possibilities are provided by the new observations of space telescopes, e.g. Kepler or TESS.

Based on observations obtained with the Apache Point Observatory 3.5-meter telescope, which is owned and operated by the Astrophysical Research Consortium, Nordic Optical Telescope, operated by the Nordic Optical Telescope Scientific Association at the Observatorio del Roque de los Muchachos, La Palma, Spain, of the Instituto de Astrofísica de Canarias, and Mercator Telescope, operated on the island of La Palma by the Flemish Community, at the Spanish Observatorio del Roque de los Muchachos of the Instituto de Astrofísica de Canarias. We thank Eva Bauwens, Bart Vandenbussche, Alexander Eigenbrod, Christoffel Waelkens, Pieter Deroo, Erik Broeders, Djazia Ladjal, Wim De Meester, Cezary Kułakowski, Evelien Vanhollebeke, Rik Huygen, Rachel Drummond, Roy Østensen, Matthieu Karrer, Elena Puga Antolín, Laurent Le Guillou, and Rosa María Domínguez Quintero for making some observations of NGC 6910. This work was supported by the NCN grants 2012/05/N/ST9/03898 and 2016/21/B/ST9/01126 and has received funding from the European Community's Seventh Framework Programme (FP7/2007-2013) under grant agreement no. 269194. PW acknowledges support from NCN grants 2013/08/S/ST9/00583 and 2015/17/B/ST9/02082. JNF acknowledges the support from the National Natural Science Foundation of China (NSFC) through the grants 11833002 and 11673003. TM acknowledges financial support from the European Space Agency through a Postdoctoral Research Fellow grant and from the Research Council of Leuven University through grant GOA/2003/04. CA and CG receive funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (grant agreement N°670519: MAMSIE). This research has made use of the WEBDA database, operated at the Department of Theoretical Physics and Astrophysics of the Masaryk University.

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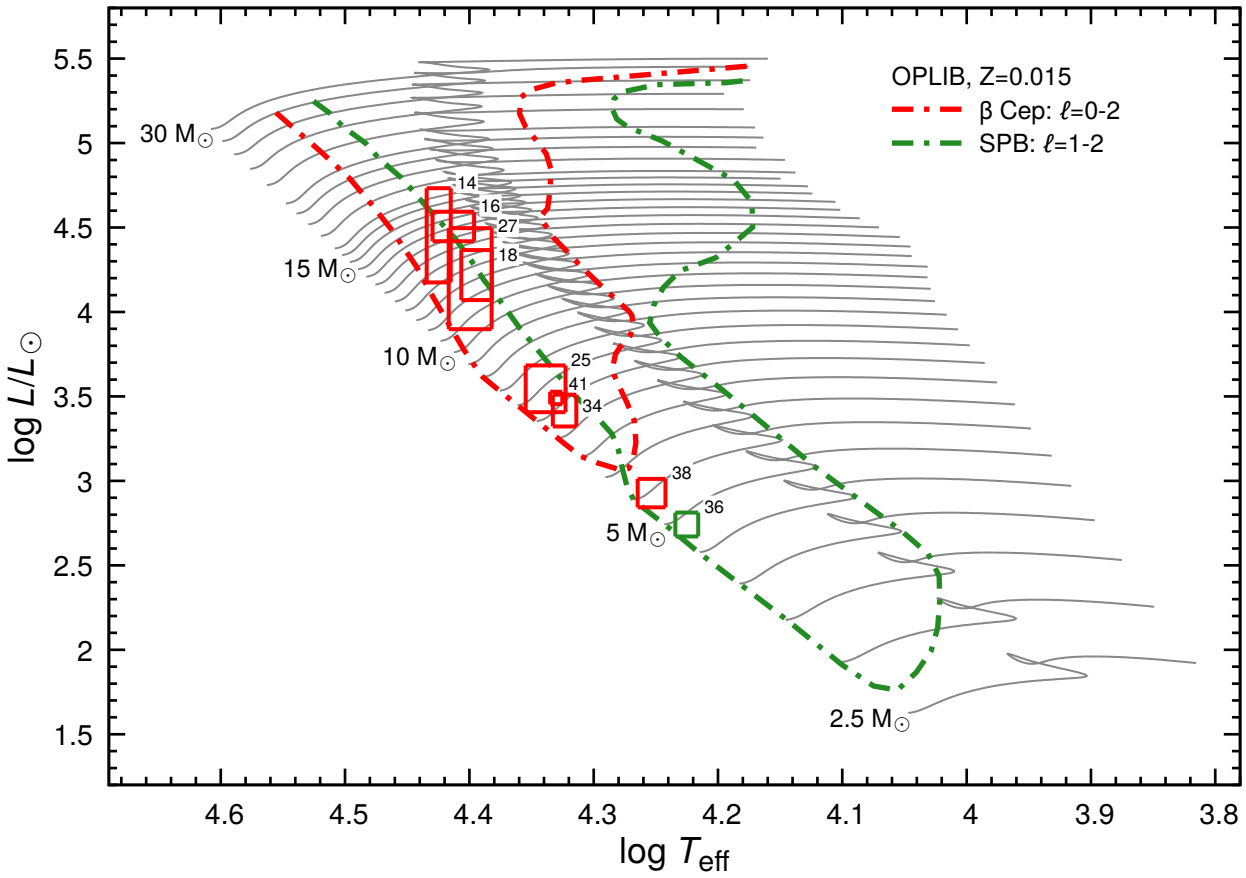

Fig. 1. Location of error boxes, obtained with ensemble asteroseismology, of the nine examined B-type pulsating stars, on the HR diagram, with evolutionary tracks and instability strips taken from Walczak et al. (2015). β Cep stars are marked with red error boxes and the one SPB star is marked with a green error box. All stars are labelled with WEBDA numbers.