# Prospects for the ensemble asteroseismology in young open clusters

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This is a progress report on the ongoing project dealing with ensemble asteroseismology of B-type stars in young open clusters. The project is aimed at searches for B-type pulsating stars in open clusters, determination of atmospheric parameters for some members, and seismic modeling of B-type pulsators. Some results for NGC 457, IC 1805, IC 4996, NGC 6910, and $\alpha$ Per open clusters are presented. For the last cluster, BRITE data for five members were used.

## 1 Introduction

Stellar clusters are known as good 'laboratories' for studying member stars. By fitting isochrones, one can obtain distance, age and sometimes get information on metallicity of a cluster. Our project is focused on finding open clusters rich in pulsating B-type stars and subsequent seismic modeling of their members by means of ensemble asteroseismology (hereafter EnsA). EnsA takes advantage of the common parameters of the members of a cluster (e.g. age and metallicity) to put additional constraints on seismic models of member stars. It is applicable to open clusters rich in massive pulsating stars. The most promising are $\beta$ Cep stars for which many interesting results were already obtained by means of seismic modeling (e.g. Aerts et al., 2003; Pamyatnykh et al., 2004; Dupret et al., 2004; Daszyńska-Daszkiewicz & Walczak, 2010). One of the best candidates for application of EnsA is NGC 6910 (Kołaczkowski et al., 2004), for which pulsation parameters were obtained as a result of the international observational campaign (Pigulski, 2008; Saesen et al., 2010). In the era of nano-satellites, new possibilities of seismic studies of stars belonging to bright, nearby star clusters occured. An example is $\alpha$ Per open cluster.

## 2 New observations and results

The results of the observations of NGC 457 and preliminary results of the search for variable stars in IC 1805 were published by Moździerski et al. (2014) and Moździerski (2012), respectively. Recently, we performed also search for variable stars in another young open cluster, IC 4996. Observations of IC 4996 were made between 2007 and 2014 in Białków Observatory (Poland) during 50 observing nights. The observations were carried out with a 60-cm reflecting telescope with the attached CCD camera covering $13' \times 12'$ field of view. About 7500 CCD frames were acquired through the $B$, $V$, $R$, $I_C$ and narrow-band H$\alpha$ filters. We detected 81 variable stars (Fig. 1), of which 71 are new. One new $\beta$ Cep star was found.

In total, in three open clusters (NGC 457, IC 1805, and IC 4996) we have detected 231 variables. Among the most interesting are: large population of SPB stars (21) in

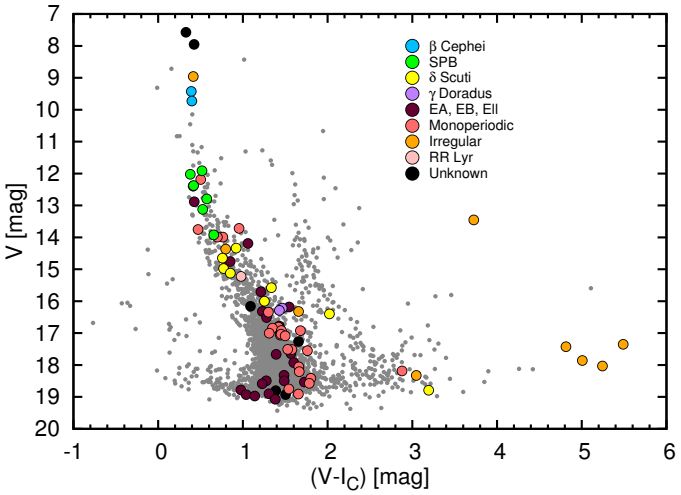


Fig. 1: Variable stars in the color-magnitude diagram of IC 4996.

NGC 457, some of them showing frequences above 3.5 $d^{-1}$, and many monoperiodic variables in IC 4996 and IC 1805 grouping in the lower parts of their color-magnitude diagrams. These are probably pre-main sequence stars. Small number of $\beta$ Cep stars in NGC 457, IC 4996, and IC 1805 either does not give, or gives marginal chance for a successful application of EnsA. Nonetheless, our study resulted in finding above mentioned groups of SPB and monoperiodic stars which in the future might be useful for better understanding of the incidence of variability in young open clusters at main sequence and pre-main sequence stages of evolution.

The best candidate for the application of EnsA is NGC 6910. The first results look promising. Using echelle spectra obtained with Apache Point Observatory (APO) ARC 3.5-m telescope and Nordic Optical Telescope (NOT), we have derived atmospheric parameters of three $\beta$ Cep stars from NGC 6910, NGC 6910-14, -16 and -18, using NLTE BSTAR2006 grid (Lanz & Hubeny, 2007) of atmosperic models. Then, effective temperatures and surface gravities of these stars were used to place them in the theoretical H-R diagram and for the mode identification. In calculations, we used Warsaw - New Jersey evolutionary code adopting OPAL opacities, solar mixture as determined by Asplund et al. (2009) and no overshooting from the convective core. Mode identification based on $B$, $V$, $I_C$ time-series photometry was performed with the methods developed by Daszyńska-Daszkiewicz et al. (2003) and Daszyńska-Daszkiewicz et al. (2005). We identified degree of the mode with frequency $f = 5.252056$ $d^{-1}$ detected in NGC 6910-14 as $l = 4$. In view of the relatively high projected rotational velocity of the star ($V_{\rm rot} = 149$ km/s), the possiblity that it is rotationally coupled $l = 2$ mode, cannot be excluded. We also identified degrees of four modes with the highest photometric amplitudes in two other $\beta$ Cephei stars, NGC 6910-16 ($f_1 = 5.202740$ $d^{-1}$ and $f_2 = 4.174670$ $d^{-1}$, both as $l = 2$) and NGC 6910-18 ($f_1 = 6.154885$ $d^{-1}$ as $l = 0$ and $f_2 = 6.388421$ $d^{-1}$ as $l = 2$). The full results of the application of EnsA to NGC 6910 will be published elsewhere.

Unfortunately, it turned out that the up-to-date BRITE observations of five B-type members of $\alpha$ Per cluster revealed only one pulsating star, HD 22192. It can

be classified as a SPB star with frequency groupings. Therefore, the cluster does not seem to be an object suitable for the application of EnsA.

*Acknowledgements.* This work was supported by the NCN grant no. 2012/05/N/ST9/03898 and has received funding from the European Community's Seventh Framework Programme (FP7/2007-2013) under grant agreement no. 269194. We thank Z. Kołaczkowski, D. Drobek, A. Majewska, M. Stęślicki, G. Kopacki, E. Niemczura and G. Michalska for making observations of IC 4996 in Białków. We thank Dr. J. Jackiewicz for making available telescope time on the APO ARC 3.5-m telescope and for his support during observations. We also thank for T. Morel and J.H. Telting for making spectroscopic observations on NOT and P. Walczak for providing some software and patient comments. This research has made use of the WEBDA database, operated at the Department of Theoretical Physics and Astrophysics of the Masaryk University. The work on $\alpha$ Per is based on data collected by the BRITE-Constellation satellite mission, built, launched and operated thanks to support from the Austrian Aeronautics and Space Agency and the University of Vienna, the Canadian Space Agency (CSA) and the Foundation for Polish Science & Technology (FNiTP MNiSW) and National Centre for Science (NCN).

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