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Applications of pulsation amplitudes and phases for B-type main sequence pulsators

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Abstract. Combined data on pulsation amplitudes and phases from multicolour photometry and spectroscopy yield constraints on mode identification as well as on mean stellar parameters. The data allow for determination of a certain complex parameter which may be compared with the model value and thus constitute a new seismic probe of stellar interior, specifically of its outer layers. We present here some results obtained for the two β Cephei stars δ Ceti and ν Eridani. We found significant differences between models calculated with opacities from the OPAL and OP projects.

Key words. Stars: β Cep pulsators – Stars: individual: δ Cet, ν Eri – Stars: atmospheres

In earlier papers (Daszyńska-Daszkiewicz et al. 2003, 2005a) we introduced a new asteroseismic probe of stellar structure. The probe is the complex parameter, f, which is the ratio of the relative luminosity variation to the radial displacement at the photosphere. The inferred f values may be compared with linear nonadiabatic model calculations and constitute a new seismic probe of subphotospheric layers, which are poorly probed by the frequency data. The empirical f values are derived from pulsation amplitudes and phases simultaneously with the ℓ degrees upon adopting adequate atmosphere models. For more details of our method we refer reader to the above mentioned papers. In those papers, we applied our method to δ Scuti variables, where we were interested mostly in probing the efficiency of subphotospheric convection.

In the present note, which is an abbreviated version of our paper (Daszyńska-Daszkiewicz et al. 2005b), we report shortly on application of our new diagnostic tool to β Cephei variables. In this case, we have expected the f parameters to be particularly sensitive to opacity in the driving zone.

For the monoperiodic β Cep star δ Cet, we confirmed the $\ell = 0$ value for the only detected pulsation mode in this star. Subject of the discussion was discrimination between fundamental and first overtone mode. Two clues were considered. First was the value of f, which depends on the radial order of the mode. The second clue was the condition of mode instability. Using models calculated with

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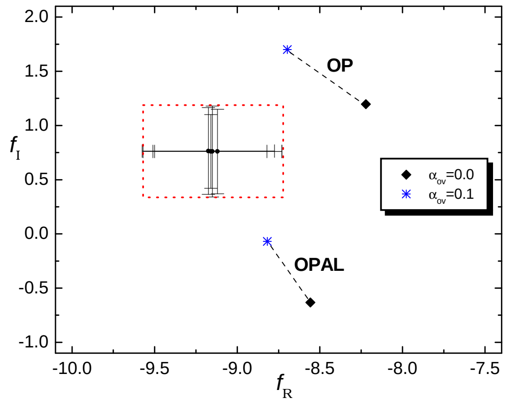

Fig. 1. The f values from data ν Eri for (points with error bars) compared with the values calculated for the seismic models of the star (see Table 1). The small spread of the observational values comes from uncertainties in $T_{\rm eff}$ and Z

Table 1. Seismic models of ν Eri calculated with the OPAL and OP opacities. The f values refers to radial mode but they are nearly the same for the $\ell = 1$, g_1 triplet.

$M/M_\odot$	$\alpha_{\rm ov}$	Z	$\log T_{\rm eff}$	f_R	f_I
		OPAL			
9.808	0.0	0.0155	4.3530	-8.56	-0.63
9.230	0.1	0.0145	4.3424	-8.82	-0.07
		OP			
9.590	0.0	0.0185	4.3396	-8.22	1.20
9.020	0.1	0.0175	4.3284	-8.70	1.70

the OPAL opacities, we found that only the first overtone identification leads to the consistency between empirical and theoretical values of f. However, in the allowed range of effective temperature, $T_{\rm eff}$, and metallicity, Z, the first overtone was found stable. With the OP opacities, we obtained consistency for the fundamental mode identification and avoided problems with the mode excitation. Therefore, unlike our predecessors, we think that the mode is more probably fundamental and not the first overtone. With this new identification, the star must be less luminous by some 40 percent.

Another object we studied was ν Eri, which is the most multiperiodic β Cep star known up to now. However, only for the four dominant peaks identified as an $\ell = 0$ singlet and $\ell = 1$ triplet, did we have sufficiently accurate data for our purpose. As for mode radial order, the only possible radial order identifications are fundamental mode (p_1) for the singlet and g_1 for the triplet. All these modes have close frequencies, thus, we have expected similar values of f and this was confirmed by our data analysis.

We constructed new seismic models fitting the dominant peak frequencies and, in addition, measured frequencies of the $\ell = 1$, p_1 triplet. In the latter case, the data allow for a unique mode identification though not for a meaningful determination of f. The observational constraints on $T_{\rm eff}$ and M_V were taken into account. The models were calculated using, both, the OPAL and the OP opacity data and assuming two values of the overshooting parameter $\alpha_{\rm ov}$. Some calculated characteristics of the models are listed in Table 1. The entries include the f parameters, which are compared with their empirical counterparts in Fig. 1. The $\ell = 0$ and the $\ell = 1, g_1$ mode are found unstable in all these models. We can see that the there is a significant difference in the stellar parameters, in particular in the f values, inferred from calculation employing opacity data from the two sources. It is worth noting that the f values calculated for models allowing some overshooting encompass the observational range, which is encouraging. However, the range of allowed parameters is still large and we cannot tell which of the two opacities better passed the observational test.

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