New windows on massive stars: asteroseismology, interferometry, and spectropolarimetry
Proceedings IAU Symposium No. 307, 2014
G. Meynet, C. Georgy, J. H. Groh & Ph. Stee, eds.

doi:10.1017/S1743921314006875

Seismic analysis of the massive β Cephei star 15 Canis Majoris

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Abstract. 15 Canis Majoris is a quite massive ($M \sim 14\,M_\odot$) main sequence pulsator of the β Cephei type. Recent photometric (Handler 2014) and spectroscopic (Saesen & Briquet, priv. comm.) observations confirm four pulsational frequencies and indicate possible additional modes. We calculated models fitting two frequencies identified as radial and dipole modes. Our analysis indicates rather effective overshooting from the convective core as well as a strong dependence of the minimal required overshooting parameter ($\alpha_{\rm ov,min}$) on the metallicity, Z ($\alpha_{\rm ov,min} \sim -2.5Z$).

When incorporating the non-adiabatic f-parameter (Daszyńska-Daszkiewicz & Walczak 2009), defined as the ratio of the bolometric flux changes to the radial displacement, significant differences between the opacity tables were obtained. The comparison of the models derived with different codes is also interesting. We used two evolutionary codes: Warsaw-New Jersey (Pamyatnykh *et al.* 1998) and MESA (Paxton *et al.* 2011) and some systematic differences were found.

Keywords. stars: individual 15CMa, stars: variables: β Cephei, stars: interiors

1. Introduction

The comparison between the observational and theoretical amplitude ratios of the light changes in the Strömgren uvy filters gave us identifications of the mode degree, ℓ, for four pulsational modes of 15 CMa. We derived $\ell = 1$ for $\nu_1 = 5.418522(3)$ c/d, $\ell = 0$ for $\nu_2 = 5.183250(6)$ c/d, $\ell = 1$ or 3 for $\nu_3 = 5.308302(8)$ c/d and $\ell = 1$ for $\nu_4 = 5.52139(2)$ c/d.

The comparison between the empirical and theoretical values of the f-parameter for the radial mode ν_2 indicates that this mode is most probably the fundamental one. The method of determination of the empirical values of the f-parameter can be found in Daszyńska-Daszkiewicz *et al.* (2003, 2005).

2. Asteroseismic models

Seismic model fitting of two well-identified frequencies, ν_2 (the $\ell = 0$ mode) and ν_4 (the $\ell = 1$ mode), is presented in Fig. 1. Since we do not know the azimuthal order of the dipole modes, we assumed $m = 0$ for ν_4. For this reason, our analysis should be treated with caution. It is interesting, however, that when we assumed ν_1 being the centroid dipole mode ($m = 0$) we could not find any seismic model fitting both ν_1 and ν_2. It may indicate that our assumption is correct, since ν_1 and ν_4 seem to belong to the same rotationally split triplet.

Models shown in Fig. 1 were calculated with the Warsaw-New Jersey evolutionary code (WNJ). In the left panel we used the OP opacity tables (Seaton 2005) and in the right panel the OPAL data (Iglesias & Rogers 1996). Modes ν_2 and ν_4 are in general unstable in almost all presented models. Only the OPAL models with small Z and high $\alpha_{\rm ov}$ are stable (upper left part of the right panel).

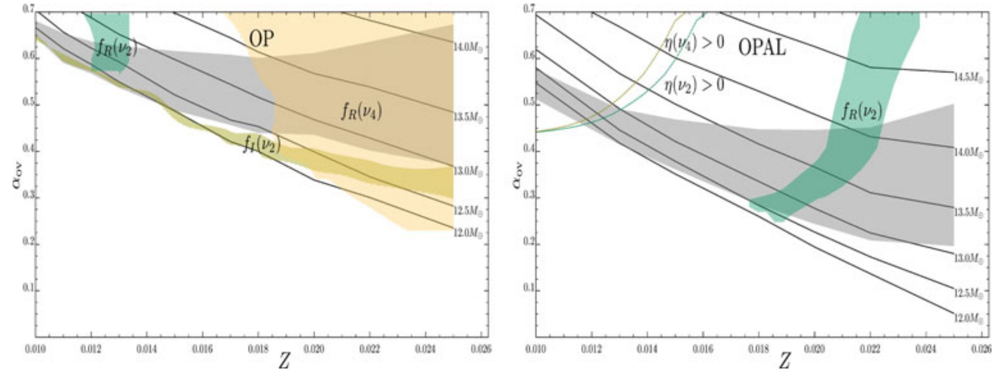

Figure 1. Seismic models that fit two frequencies: ν_2 (the $\ell = 0$ mode) and ν_4 (the $\ell = 1$ mode). On both panels we overplot lines of constant mass (black solid). Grey areas indicate models lying inside the observational error box of the effective temperature ($T_{\rm eff}$) and surface gravity ($\log g$) of 15 CMa, and their error estimates were taken from Shobbrook *et al.* (2006). Regions labelled with $f_{\rm R}(\nu)$ and $f_{\rm I}(\nu)$ mark models that fit the real and imaginary parts of the empirical values of the f-parameter, respectively.

Unfortunately, we were unable to find seismic models fitting both the real and imaginary parts of the empirical f-parameter, neither for ν_2 nor ν_4. This may indicate problems with the opacity coefficient. For B-type pulsators, the f seismic tool probes in particular stellar metallicity and opacities. Although in case of 15 CMa there is no clear preference towards any opacity table, we can notice that the OPAL models can not fit the imaginary part of the f-parameter, neither for ν_2 nor ν_4. There is also a lack of models fitting the real part of f for ν_4 while $f_{\rm R}$ for ν_2 indicates much higher metallicity.

In general, the compatibility between WNJ and MESA models is rather good (MESA models are not shown), although the f-parameter of WNJ models indicates slightly larger metallicity than in case of MESA models. MESA models have also higher instability parameter, η.

Acknowledgments. We gratefully thank Sophie Saesen and Maryline Briquet for providing the spectroscopic data and Anne Thoul for helpful discussions. Calculations have been carried out using resources provided by Wroclaw Centre for Networking and Supercomputing (http://wcss.pl), grant No. 265. This study is supported by the Polish National Science Centre grants No DEC-2013/08/S/ST9/00583 and 2011/01/B/ST9/05448.

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