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Galactic Cepheid pulsation models: dependence on input parameters

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Abstract. We present an overview on pulsation properties of new sequences of Galactic Cepheid (Y=0.28, Z=0.02) envelope structures constructed by adopting updated input physics in both linear and nonlinear hydrodynamical models. We also investigate the dependence of pulsation predictions on the Mass-Luminosity (ML) relation as well as on the spatial resolution across the Hydrogen and the Helium partial ionization regions.

Key words. Cepheids – Galaxy: stellar content – hydrodynamics – stars: evolution – stars: oscillations

1. Introduction

The equation of state (EOS) and the opacity are fundamental ingredients to properly compute the physical structure of stellar envelopes. In particular, hydrodynamical models of variable stars require high-derivatives of the thermodynamic quantities (see, e.g., Christy 1969; Stellingwerf 1974, 1982). Since the driving mechanisms are connected with envelope regions where temperature and density gradients present sudden changes, the accuracy in the opacity and EOS derivatives is a key feature in pulsation models.

To study the dependence on the EOS, we constructed several sequences of nonlinear and time-dependent convective models with stellar masses ranging from 5 to 13 $M_{\odot}$ by using the simplified EOS originally developed by Stellingwerf (Stellingwerf 1982) and the recent analytical EOS developed by Irwin (Cassisi, Salaris, and Irwin 2003; Irwin et al. 2003). We also investigated the dependence on the ML relation by fixing the luminosity of Cepheids according to the ML relation recently derived by Bono et al. (2000) and by comparing the predicted pulsational properties with the results by Bono, Castellani, and Marconi (2000, hereinafter BCM00), which models were all based on higher luminosity levels. Finally, the finer spatial resolution adopted across the H and the He ionization regions in current models allow us to test the dependence of the observables theoretically predicted on this further ingredient (see also Petroni et al. 2003 and references therein).

2. Results

Figure 1 shows the comparison between predicted nonlinear Fundamental (F) and First Overtone (FO) edges according to the

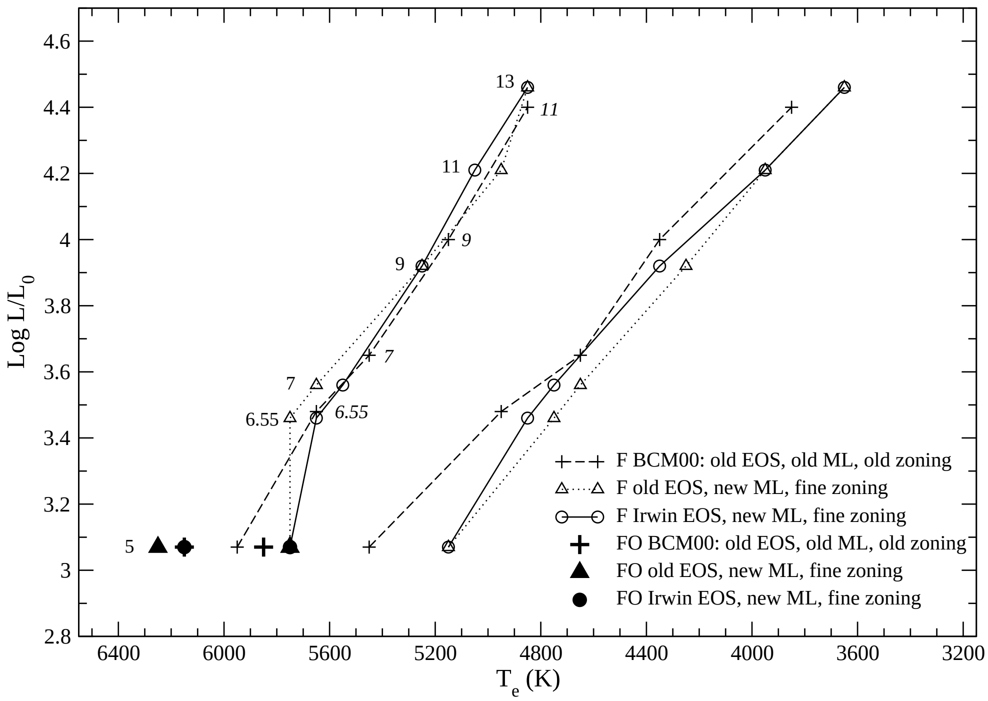

Fig. 1. Comparison in the HR diagram between nonlinear F and FO blue and red edges according to models constructed using different EOS (the old one by Stellingwerf and the new EOS by Irwin), different ML relation and spatial resolution (zoning), as labeled.

Stellingwerf (triangles) and to the Irwin (circles) EOS, when the ML relation by Bono et al. (2000) and a finer zoning are adopted in the computations. The edges predicted by the models constructed by BCM00 are also indicated (pluses). We found that the new theoretical framework (new input physics and parameters) moves the instability strip toward cooler effective temperatures by up to 200-300 K for the lower mass values. This effect is mainly caused by the finer spatial resolution adopted in current calculations, while the ML relation and the EOS play a secondary role. The top panel of Fig. 2 shows predicted bolometric amplitudes for the sequences of models constructed by adopting the Irwin EOS (solid line) and the Stellingwerf EOS (dotted line) as a function of period (the so-called Bailey Diagram). Only marginal differences arise between the two sets of models over the entire mass range. Data plotted in the middle panel show the dependence of luminosity amplitudes on ML relation and spatial resolution. As a whole, the direct comparison between new current predictions and the old ones by BCM00 is shown in the bottom panel of the same figure. The analysis of the bolometric amplitudes indicates that the maximum effect of the EOS occurs for intermediate-mass variables, and the effect of the ML relation evidences only for high-mass Cepheids. It is worth noting that the increase in the spatial resolution across the partial ionization regions affects the pulsation properties of the whole mass range. In particular, note that the new models with masses $M = 6.55$ and 7 $M_{\odot}$ present the typical *double-peaked* distribution of Bump Cepheids (Bono, Marconi, & Stellingwerf 2000), while the 7 $M_{\odot}$ models constructed by BCM00 do not show

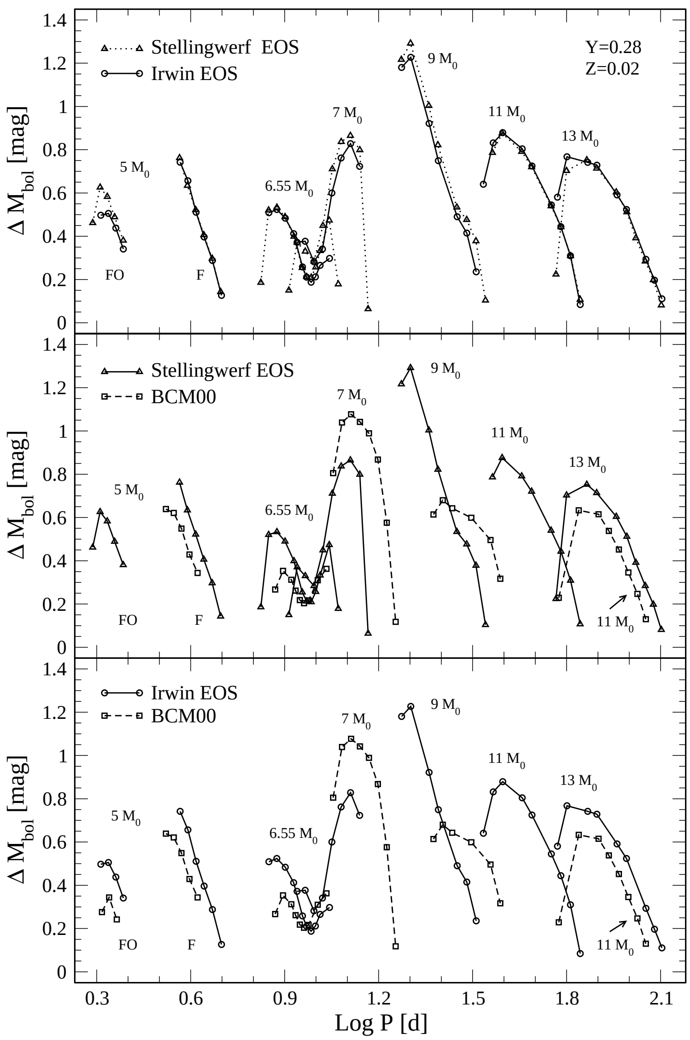

Fig. 2. Comparison between bolometric amplitudes based on pulsation models constructed by adopting different EOS (top), different ML relation and spatial resolution (middle), and different EOS, ML relation, and spatial resolution (bottom).

such a behavior. Figure 3 shows the theoretical Period-Radius (PR) relation at solar metallicity predicted by current framework compared with the PR relation supplied by BCM00. The difference between these two relations ranges from 0.005 to 0.01 dex when moving from $\log P = 0.5$ to $\log P = 2.0$.

3. Conclusions

The quoted results reveal that, more than the EOS and the ML relation, the spatial resolution affects either the location of the instability strip or the features of the predicted bolometric amplitudes in the Bailey Diagram. The interesting results arising for the Bump Cepheid models

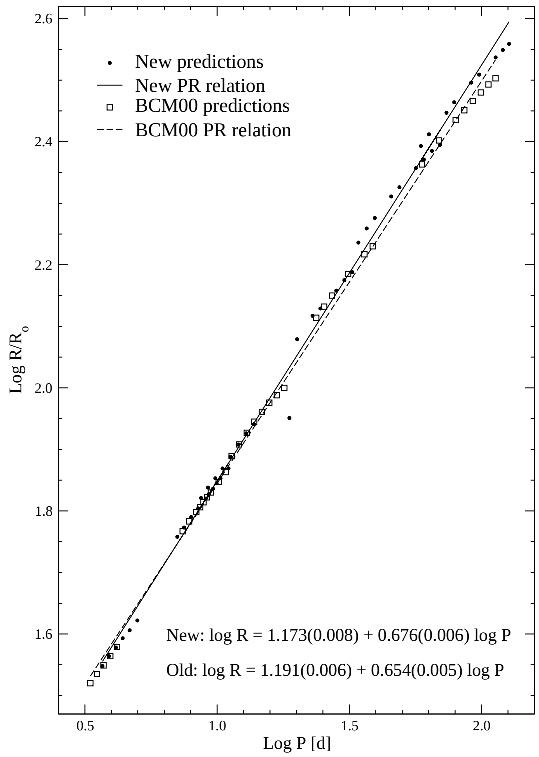

Fig. 3. Comparison between different theoretical PR relations. Filled circles show the nonlinear radii obtained with current models; open squares refer to results by BCM00; solid and dashed lines represent the PR relations obtained for these two theoretical frameworks, respectively. Analytical expressions are also presented with errors on coefficients explicitly indicated, with the radius R in solar units and the period P in days.

need a more detailed investigation (see Petroni et al. 2003).

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