Spectroscopic properties of a two-dimensional time-dependent Cepheid model II. Determination of stellar parameters and abundances

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arXiv:1711.00236 Standard spectroscopic analyses of variable stars are based on hydrostatic one-dimensional model atmospheres. This quasi-static approach has theoretically not been validated. We aim at investigating the validity of the quasi-static approximation for Cepheid variables. We focus on the spectroscopic determination of the effective temperature $T_{\rm eff}$, surface gravity log g, microturbulent velocity $\xi_{\rm t}$, and a generic metal abundance log A – here taken as iron. We calculate a grid of 1D hydrostatic plane-parallel models covering the ranges in effective temperature and gravity encountered during the evolution of a two-dimensional time-dependent envelope model of a Cepheid computed with the radiation-hydrodynamics code CO5BOLD. We perform 1D spectral syntheses for artificial iron lines in local thermodynamic equilibrium varying the microturbulent velocity and abundance. We fit the resulting equivalent widths to corresponding values obtained from our dynamical model for 150 instances in time covering six pulsational cycles. In addition, we consider 99 instances during the initial, non-pulsating stage of the temporal evolution of the two-dimensional model. In the most general case, we treat $T_{\rm eff}$, log g, $\xi_{\rm t}$, and log A as free parameters, and in two more limited cases we fix $T_{\rm eff}$ and log g by independent constraints. We argue analytically that our approach of fitting equivalent widths is closely related to current standard procedures focusing on line-by-line abundances. For the four-parametric case, the stellar parameters are typically underestimated exhibiting a bias in the iron abundance of ≈ -0.2 dex. To avoid biases of this kind it is favorable to restrict the spectroscopic analysis to photometric phases $\phi_{\rm ph} \approx 0.3 \ldots 0.65$ using additional information to fix effective temperature and surface gravity. Hydrostatic 1D model atmospheres can provide unbiased estimates of stellar parameters and abundances of Cepheid variables for particular phases of their pulsations. We identified convective inhomogeneities as the main driver behind potential biases. For obtaining a complete view on the effects when determining stellar parameters with 1D models, multi-dimensional Cepheid atmosphere models are necessary for variables of longer period than investigated here.

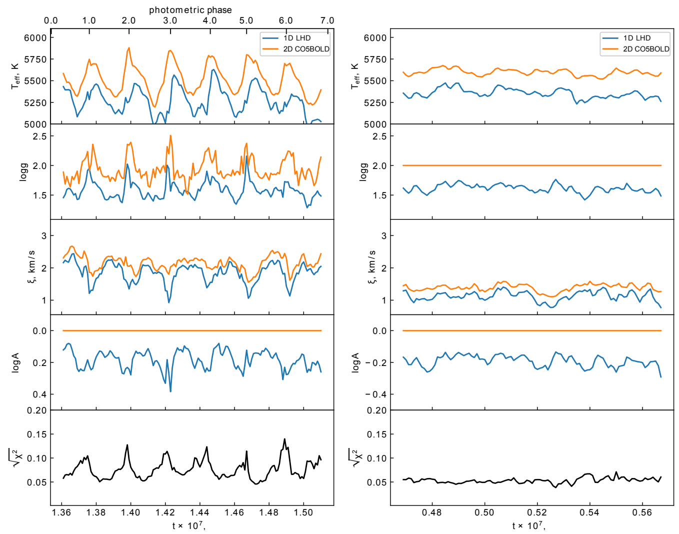

Fig. 5: The result of the four-parametric fitting for the pulsating (left panel) and non-pulsating (right panel) regimes. The parameters of the 2D model are shown by orange lines for both regimes. The reconstructed parameters with the 1D LHD grid are shown by blue lines. The relative RMS deviation $\sqrt{\xi^2}$ in line strengths between the 2D and 1D models is shown by a black line.

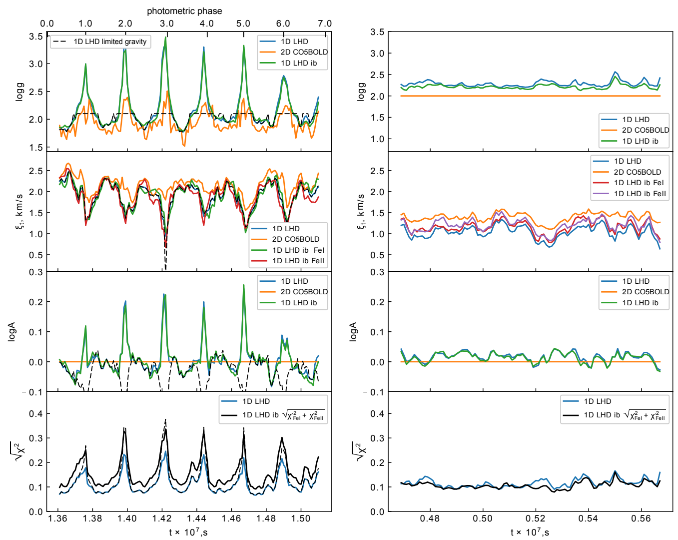

Fig. 7: The result of the three-parametric fitting for the pulsating (left panel) and non-pulsating (right panel) regimes. The parameters of the 2D model are shown by orange lines for both regimes. The reconstructed parameters with the direct three-parametric fitting using the 1D LHD grid are shown by blue lines. Results using the ionization balance are shown by green, brown and solid black lines. For the pulsating regime the result of the experiment with a gravity limit for the maximum compression phase is shown by the dashed black line. The relative RMS deviation $\sqrt{\chi^2}$ in line strengths between the 2D and 1D models is shown by the solid blue and black lines for the direct three-parametric fitting and fitting using the ionization balance condition, respectively.

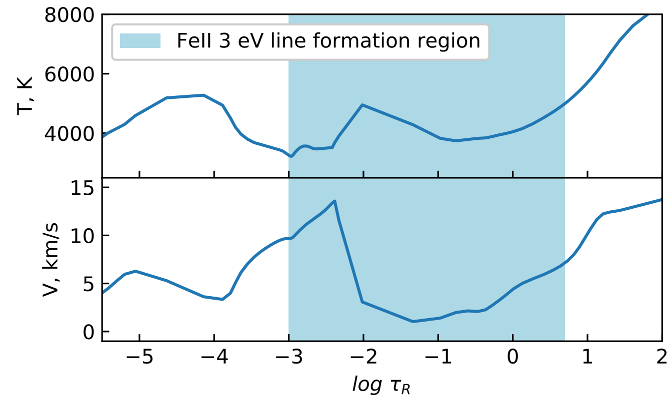

Fig. 4: Vertical thermal and radial velocity profiles of the section of the two-dimensional model where the emission line profile of the strongest feii 3 eV line occurs. The line formation region is indicated by the light blue area.

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