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IMPLEMENTATION OF OPLIB MONOCHROMATIC OPACITIES IN THE CESAM2K20 EVOLUTION CODE AND IMPACTS ON SOLAR MODELS

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Abstract. At Los Alamos National Laboratory (LANL) new generations of opacities have been developed: these OPLIB monochromatic opacities, computed with the ATOMIC code, have never been used in stellar evolution codes. This work aims to implement these new monochromatic opacity tables in the Cesam2k20 evolution code in order to see impacts on solar models. The obtained models are different from those computed with OP monochromatic opacity tables. It is thus interesting to test models computed with OPLIB monochromatic opacities with helioseismic constraints.

Keywords: monochromatic opacity, solar model, Cesam2k20

1 Introduction

For many years, intense efforts have been made to produce complete and accurate opacity tables that can be used in stellar evolution codes. We can classify these tables in two categories: the first concerns tables containing Rosseland mean opacity (RMO) calculated for predefined chemical compositions, while the second concerns tables with monochromatic opacities such as the OP opacity tables (Seaton 2005). These monochromatic opacities are rarely used, even if they allow to obtain coherent RMO with the chemical composition. At LANL, new generations of opacities have been developed : the OPLIB monochromatic opacities (Colgan et al. 2016), computed with the ATOMIC code (Magee et al. 2004; Hakel et al. 2006; Fontes et al. 2015). This monochromatic data has never been used in stellar evolution codes. Here we present the first implementation of this new OPLIB data in the Cesam2k20[*] (Morel & Lebreton 2008; Marques et al. 2013) stellar evolution code and associated solar models.

2 Method

The monochromatic opacities already implemented in Cesam2k20 are OP tables. These tables give opacities along four dimensions : element, temperature, electron density, and frequency. OPLIB tables can be queried from a web interface[†] but are parameterized using the mass density ρ (g.cm^{-3}) instead of the electron density N_e(cm^{-3}). We built a code[‡] that can retrieve requested OPLIB opacities as tables in the OP format. We used the following equation to find a ρ corresponding to N_e: $N_e = \frac{\rho \times Z}{\mu}$, with Z the mean ionization and μ the mean molecular weight. As a result, we have 137640 spectra organised from hydrogen to zinc for temperatures in the range [5.802×10^3 ; 1.16×10^9] K, for mass densities ρ from 10^{-8} g.cm^{-3} up to 10^4 g.cm^{-3}, and for 14900 frequency values (Colgan et al. 2016).

3 Preliminary results

To validate the retrieved monochromatic opacity tables, we compare the RMO for all grid points between OP and OPLIB tables at the composition at the base of the convective zone of the Sun. The relative difference of the RMO between those tables, zoomed around a solar-calibrated model in Fig.1 (**left**), are small. However, a difference of up to 10% can be seen close to the core (high temperatures). These differences will impact the internal structure of stellar models.

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[*] Cesam2k20 : `https://www.ias.u-psud.fr/cesam2k20/home.html`

[†] TOPS opacity : `https://aphysics2.lanl.gov`.

[‡] Based on the pytopsscrape code : `https://github.com/tboudreaux/pytopsscrape`.

In order to validate the OPLIB opacities' implementation, we generate a solar-calibrated model using these new tables. The calibrated parameters are the initial helium mass fraction, the initial metallicity, and the convective mixing length parameter. The optimal values of those parameters are presented in Tab.1 (**left**) and they are very close to those of OP. However, in Fig.1 (**right**), the relative difference in the RMO between both models varies, leading to an impact on the structure. With this new opacity data, the radius of the base of the convective envelope (r_b) for the solar model is larger than for OP, and the surface helium abundance (Y_s) is smaller (Tab.1, **right**). Despite the fact that these models do not include an adequate transport of chemical elements (e.g. to reproduce the lithium and beryllium surface abundances), it opens the possibility of testing this new data with more advanced helioseismic signatures (see e.g. Deal et al. 2025, and references therein). Overall, even if there are some differences due to interpolation, we obtained results similar to Boudreaux & Chaboyer (2023) for which RMO tables with a predefined chemical composition were used.

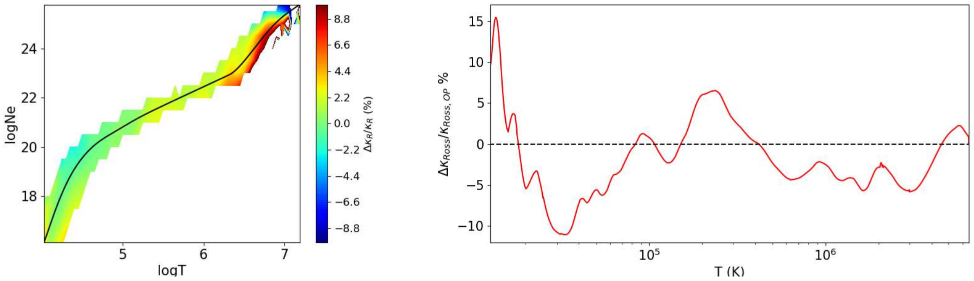

Fig. 1. Relative difference of the RMO between OP and OPLIB data points around the solar model (**left**) and between OP and OPLIB tables on the internal structure (**right**).

	OPLIB	**OP**
Y_0	0.262401	0.262861
Z_0	0.015550	0.015474
α_0	1.76995	1.78893

	Basu & Antia (2008)	**OPLIB**	**OP**
$r_b(R_\odot)$	0.713	0.725927	0.723081
Y_s	0.248	0.233551	0.234929

Table 1. Optimal (**left**) and observable (**right**) parameters found for the solar models after calibration.

4 Conclusions

Using the monochromatic OPLIB data, we obtain results similar to previous works (Turck-Chièze et al. 2016) that validate the implementation method. We can already see differences between the RMO obtained with OP and OPLIB tables that will have an impact on the internal structure of solar models. Therefore, it will be interesting to test models computed with OPLIB monochromatic opacities with helioseismic constraints.

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