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White dwarf cooling sequences: theoretical uncertainties

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Abstract. The white dwarf (WD) cooling times are largely affected by the assumption on the conductive opacity. In the present work we computed various cooling sequences for a typical DA WD of mass 0.6 $M_\odot$ under different choices for the electron conductivity. We conclude that the present uncertainty on the times at the faint end of the cooling sequence ($\log L/L_\odot \sim -5.5$) is of the order of 17%, which correspond to about 2 Gyr.

Key words. stars: evolution – stars: white dwarf

As early recognized by Schmidt (1959), the white dwarfs (WD) can be used as cosmic clocks. Nevertheless, only very recently the WD cosmo-cronology has become an actual and feasible tool, thanks to both the growing availability of high quality data and the improvement of the understanding of the high density matter behavior. However, the most recent WD models predict cooling times significantly different. It would be wise to identify the main sources of the quoted discrepancies before using cooling sequences as cronometers.

In a very recent paper (Prada Moroni & Straniero 2002), we have begun to address this issue computing new models of WDs relying on the most updated physical inputs. In the quoted work, we analyzed the uncertainties due to the assumptions about the main input physics (equation of state, radiative and conductive opacities, reaction rates, etc.) and to the progenitor history (chemical composition, mass loss, etc.). In the present contribution we will narrow the analysis on the conductive opacity that is one of the main sources of theoretical uncertainty. Figure 1 shows the extreme sensitivity of the cooling rate on the adopted conductive opacities tables. The Hubbard & Lampe (1969, hereafter HL69) should not be used for the C/O core due to a dated treatment of the crystallization. On the other hand, the more recent opacities by Itoh and coworkers (Itoh et al. 1983; Mitake et al. 1984; Itoh et al. 1993, hereafter I93) are accurate only in the high-degenerate regime (lets say $\theta \leq 0.1$), namely in the inner layers, since they underestimate the electron-electron interaction. Figure 1 also shows a model with a combination of the

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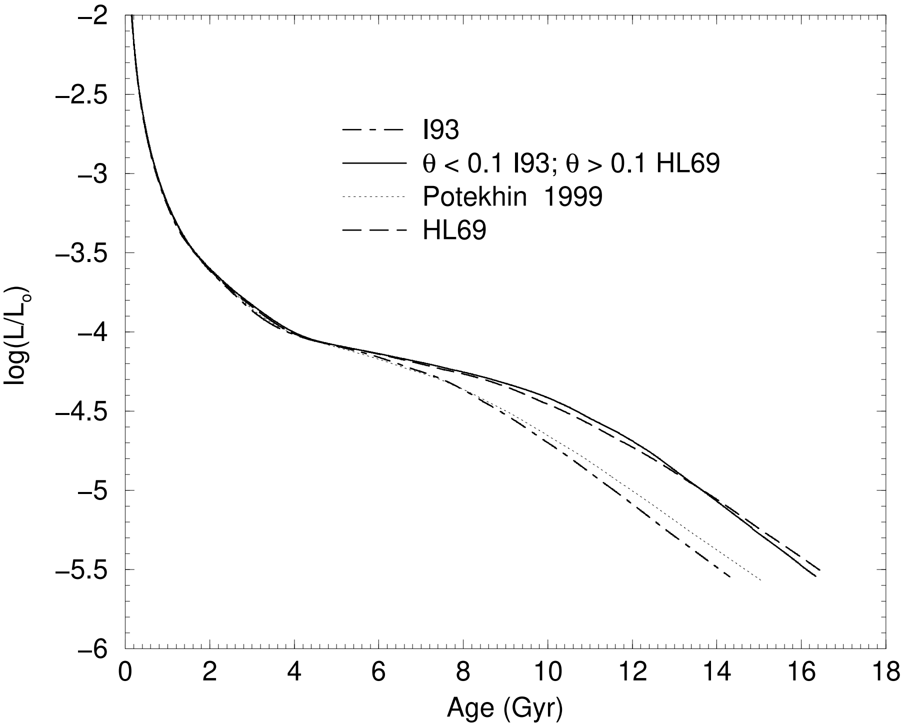

Fig. 1. Theoretical cooling sequences for a C/O DA WD of 0.6 $M_\odot$ under different prescriptions for the conductive opacity. I93: Mitake et al. (1984) for the fluid phase and Itoh et al. (1993) for the solid phase (dot-dashed line); I93 for the fully degenerate regime ($\theta \leq 0.1$) and HL69 for the partially degenerate regime (solid line); Potekhin et al. (1999, dotted line); HL69: Hubbard & Lampe (1969, dashed line).

two previous opacities. The numerical experiment shows the very tricky role played by the conductive opacity in the weakly-degenerate regime. Since the differences of these two theoretical prescriptions imply a 17% variation in the estimated WD age we conclude that the calculation of the conductive opacities deserves much attention. In this context a recent paper by Potekhin et al. (1999, see also Potekhin 1999) address this problem. The conductive opacity obtained by Potekhin and coworkers are intermediate between those of HL69 and I93. Nevertheless, as shown in Fig. 1, the resulting cooling sequence does not substantially differs from the one obtained by using the I93.

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