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Low-mass stellar models with new opacity tables and varying α-element enhancement factors

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Abstract. We have computed new models for stars of low and intermediate mass, with varying degrees of α-element enhancement factors, using new low-temperature molecular opacities. We present some of the effects found.†

Keywords. stars: general, evolution, low-mass

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1. Motivation

The increasing demands of stellar population synthesis for more accurate stellar models has led to the necessity for a fully self-consistent treatment of chemical compositions in the models. While we are far from considering any mixture correctly, the current development is for consistent models and spectra for α-enhanced compositions. One such example is presented by P. Coelho in this meeting. For this project we calculated new stellar models for both solar-scaled and α-enhanced compositions of varying total metallicity. For the α-elements a constant enhancement of 0.4 dex was chosen. We produced solar and α-enhanced models for three [Fe/H]-values. For [Fe/H] $= -0.5$ the two mixtures are $X = 0.743$, $Z = 0.032$ (solar) and $X = 0.739$, $Z = 0.011$ (α-enhanced). At [Fe/H] $= 0.0$ we have $(X, Z) = (0.718, 0.017)$ resp. $(0.679, 0.032)$, and for [Fe/H] $= 0.2$ finally $(X, Z) = 0.708, 0.026$ (solar) and $(0.642, 0.048)$ (α-enhanced).

So far, models between $M = 0.6\,M_\odot$ and $10\,M_\odot$ have been calculated. We followed the evolution from the MS to the RGB tip, resp. the early AGB, resp. the end of core He burning.

2. Opacity effects

Opacity tables are not always available for the exact model composition. We had available low-temperature tables with varying internal α-element enhancements as in Salaris & Weiss (1998), calculated with the code by Alexander & Ferguson (1994), but also new ones for the constant enhancement factors given above. The latter were specifically produced with the code of Ferguson *et al.* (2005). Consistent high-T OPAL tables (Iglesias & Rogers 1996) were combined with these. This allowed us to investigate the influence of *varying degrees of individual α-element enhancements* on the models. Fig. 1 (left panel) shows the comparison of evolutionary tracks for stars with mass between 0.6 and 1.3 $M_\odot$ with either variable (case A; solid) or constant (case B; dotted lines) α-enhancements.

† The extended version of this paper is available as `astro-ph/0605666`

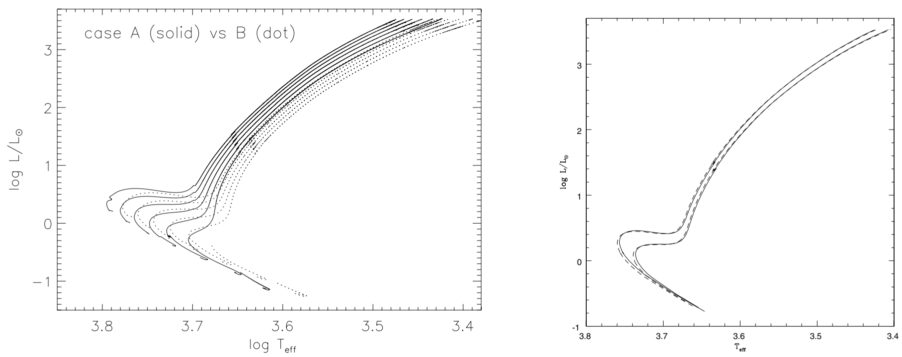

Figure 1. Left: Stellar models for $X = 0.679$, $Z = 0.032$ using opacity tables with either variable (solid) or constant (dotted lines) α-element enhancement factors. Right: Isochrones for 8 and 14 Gyr for models with $Z = 0.032$, fully self-consistently calculated, including all opacity tables for a variable (dashed) or constant (solid; slightly lower $T_{\rm eff}$ at the turn-off) α-enhancement.

There were surprisingly large differences between the two sets of models: (i) the "variable α" tables resulted in much warmer $T_{\rm eff}$ (up to +250 K), and (ii) the lifetimes were up to 15% shorter than in the "constant α" case. It turned out that theses two effects can be ascribed separately to (i) the low-T opacity tables of 1994, producing the higher temperatures, and (ii) the chemical composition of the high-T tables, which results in consistently higher opacities for temperatures between 10^4 and 10^7 K.

The first effect is due an error in the production of these specific low-T tables in 1994, the second one is real as was confirmed by test calculations using Opacity Project data. With the new code by Ferguson *et al.* (2005) new "variable α" tables have been produced, which agree well with those for constant α-enhancement; $T_{\rm eff}$ differences are reduced to the 10 K level or below. The evolutionary age differences at given mass remain.

3. Consequences

The error in the old low-T opacity tables becomes significant for $Z \gtrsim 0.5\,Z_\odot$; models which used these specific tables should be recalculated with corrected tables (e.g. Salasnich *et al.* 2000). For lower Z the effect vanishes, and the tracks are no longer affected; work on globular clusters, such as Salaris & Weiss (1998), remains valid. Only the low-T tables of our group were affected; it is not an error in the Alexander & Ferguson (1994) code. The influence of individual element abundances on stellar lifetimes is real, but isochrones are almost identical in their HRD-location (Fig. 1, right panel), although TO-masses differ by about $0.05\,M_\odot$. For accurate stellar parameters, including mass and age, all element abundances may prove significant, in particular that of oxygen.

References

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