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New Padova Isochrones: extended Z-Y plane and updated AGB models

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Abstract. The recent suggestions of significant helium enrichment in some globular clusters pointed out the usefulness of stellar tracks and isochrones covering an extended region of the Z-Y plane. New evolutionary models grids have been computed to allow people to model stellar populations for different helium enrichment laws. The extension of TP-AGB computations until the end of the thermal pulses by means of new synthetic models are relevant for stellar populations analyses in the near-infrared photometric bands.

Key words. Stars:structure – Stars: evolution – Stars: low mass – Stars: AGB

1. Introduction

Grids of stellar models in general adopt high $\Delta Y/\Delta Z$ values for the helium enrichment in order to fit both the primordial and the solar initial He content. Recently WMAP has provided a value of the primordial helium ($Y \sim 0.248$, Spergel et al. 2003, 2006), significantly higher than the value assumed in previous stellar models (0.23), thus changing the value of helium enrichment requested to fit the solar value. From observations there are determinations of $\Delta Y/\Delta Z$ spanning a large range of values (Pagel & Portinari 1998, Lebreton et al. 2001, Jimenez et al. 2003). Recently evidence has been found for significant variations in the helium content in some globular clusters like ω Cen, NGC 2808 and NGC 6441. According to Piotto et al. (2005), only greatly enhanced helium can explain the color difference between the two main sequences in ω Cen. In NGC 2808 a helium enhanced population can explain the MS spread and the HB morphology (Lee et al. 2005, D'Antona et al. 2005), and according to Piotto et al. (2007) its triple main sequence can be attributed to successive rounds of star formation with different helium abundances. These different problems and/or constraints have prompted us to compute new stellar evolutionary tracks and isochrones covering an extended region of the Z-Y plane allowing people to model stellar populations for different He enrichment values. An important update of the database is the extension of stellar models and isochrones until the end of the TP-AGB, particularly relevant for stellar population analyses in the near-infrared, where the contribution of AGB stars to the integrated photometric properties is significant.

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2. Input physics, range of Z-Y values and new TP-AGB models

Several grids of stellar models were computed with initial mass from 0.15 to $20M_{\odot}$ with initial chemical composition with $0.0001 \leq Z \leq 0.070$ and for different helium content in the range $0.23 \leq Y \leq 0.46$ as shown in Table 1. For each value of Z the fractions of different metals follow a scaled-solar distribution as compiled by Grevesse & Noels (1993). The evolutionary phases covered by the grids extend from the zero age main sequence (ZAMS) up to either the start of the thermally pulsing asymptotic giant branch (TP-AGB) phase or carbon ignition, depending on the mass. All tracks are complemented with the TP-AGB phase as described in the following. The input physics of these new stellar models is the same as in Girardi et al. (2000), but for updates in the opacities, in the rates of energy loss by plasma neutrinos (see Salasnich et al. 2000), and for the different way the nuclear network is integrated (Marigo et al. 2001). Calibration of the solar model fixes the value of the mixing length parameter of the Böhm-Vitense(1958) theory at 1.68. The extension of the convective boundaries is estimated by means of an algorithm which takes into account overshooting from the borders of both core and envelope convective zones (Bressan et al. 1981, Alongi et al. 1991, Girardi et al. 2000).

The new synthetic TP-AGB computations adopt low-temperature opacities properly evaluated for the chemical mixtures of evolving TP-AGB envelopes (instead of usual scaled-solar ones with C/O ~ 0.48). The change in the dominant opacity sources, as the C/O ratio grows from < 1 to > 1, causes a significant cooling of the carbon rich models (with C/O > 1). These TP-AGB models with variable molecular opacities are able to reproduce the observed range of effective temperatures and C/O ratios of C-type giants in the solar neighborhood, otherwise failed with scaled-solar mixtures. In addition to the molecular opacities the new TP-AGB tracks are significantly improved in different aspects (see Marigo & Girardi 2007).

Table 1. Combinations of Z and Y of the computed tracks

Z	Y1	Y2	Y3	Y4	Y5	Y6
0.0001	0.23	0.26	0.30		0.40	
0.0004	0.23	0.26	0.30		0.40	
0.001	0.23	0.26	0.30		0.40	
0.002	0.23	0.26	0.30		0.40	
0.004	0.23	0.26	0.30		0.40	
0.008	0.23	0.26	0.30	0.34	0.40	
0.017	0.23	0.26	0.30	0.34	0.40	
0.040		0.26	0.30	0.34	0.40	0.46
0.070			0.30	0.34	0.40	0.46

3. Isochrones

Isochrones are computed updating and improving the algorithm of "equivalent evolutionary points" used in Bertelli et al. (1994) and Girardi et al. (2000). There are 39 new sets of stellar tracks available in an extended Z-Y plane and an interpolation scheme has been tuned up to obtain isochrones for whatever Z-Y combination and to simulate stellar populations for the required helium enrichment law. Figures 1 and 2 show two examples of isochrones for chemical compositions intermediate among those of the sets of computed evolutionary tracks. The new synthetic TP-AGB models allow the extension of the isochrones until the end of the thermal pulses along the AGB. In Figure 3 isochrones are shown for the same metallicity (Z=0.001) and different helium content (Y=0.23 - solid line, and Y=0.40 - dashed line). Also in this case the isochrones are extended until the end of the thermal pulses along the AGB. Even if in the evolutionary tracks the luminosity is higher when the helium content increases, the evolved portion of the isochrones with lower helium is more luminous. This effect is related to the interplay between the increase in luminosity and the decrease in lifetime of stellar models with higher helium content (at the same mass and metallicity).

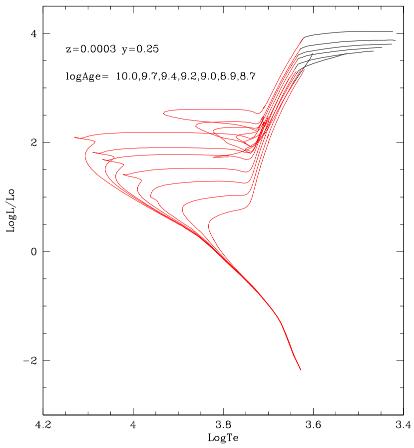

Fig. 1. Isochrones for a chemical composition intermediate among those of the computed tracks. The new synthetic TP-AGB models allow the extension of the isochrones until the end of the thermal pulses along the AGB.

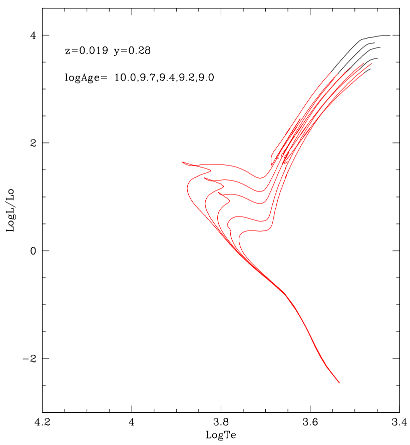

Fig. 2. Isochrones for the chemical composition Z=0.019, Y=0.28 intermediate among those of the computed tracks. The same as in Figure 1 for the AGB.

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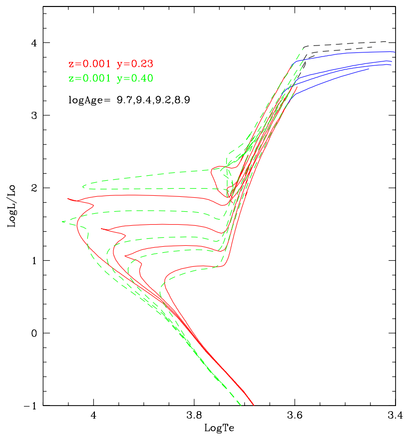

Fig. 3. Comparison of isochrones for Z=0.001 and different helium content: Y=0.23 and Y=0.40. Solid lines correspond to Y=0.23 and dashed to Y=0.40. Also in this case the isochrones are extended until the end of the thermal pulses along the AGB.

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