EFFECTS OF ENVELOPE OVERSHOOT ON INTERMEDIATE MASS STARS

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ABSTRACT. We find that a certain amount of non-local overshoot at the base of the outer convective envelope affects the evolution of intermediate mass stars in the H-R diagram, producing extended loops even for models computed with significant overshoot from the central convective core, improving in this way upon a weak point of models with core overshoot.

Alongi *et al.* (1990a,b) have found that about half a pressure scale height below the Schwarzschild border should be mixed with the convective envelope in low mass stars to shift the bump in the luminosity function of globular clusters to the absolute magnitude indicated by Fusi-Pecci *et al.* (1989). If we assume that envelope overshoot is totally responsible for the required magnitude shift (0.415Mv), we need Λ_{en}=0.7. Here, we examine the implications of this assumption on intermediate mass stars. In fact, models with core overshoot, while providing nearly the observed lifetimes of the main burning phases, cannot reproduce the observed morphology of the loops even for the low metallicities appropriate to the LMC clusters (e.g. Vallenari *et al.* 1990 and references). This is even more puzzling, since in those studies the enhanced rate of the $^{12}C\ (\alpha, \gamma)^{16}O$ reaction (Caughlan *et al.* 1985, CFHZ85) is adopted, which is known to favour extended loops (Brunish & Becker 1990). Recently, however, (Caughlan & Fowler 1988, CF88), the above reaction rate has been lowered to about its 1975 value (Fowler *et al.* 1975, FCZ). In view of the above, we computed evolutionary tracks for the 4,5,6,7,9 $M_\odot$ stars with chemical composition typical of most of the LMC clusters (Z=0.008 and Y=0.250), the Los Alamos Opacity Library, the new $^{12}C\ (\alpha, \gamma)^{16}O$ reaction rates (CF88) and adopted either the classical treatment of convection (with semiconvection during central He-burning), or a non-local overshoot from the convective core (Bertelli *et al.* 1985) and the convective envelope. We analyzed the stars with mass of 5 and 7 $M_\odot$, whose evolution is well representative of the young and intermediate age clusters. Table 1 summarizes a few basic quantities of these models, such as the H-burning and He-burning lifetimes (labelled as H and He), the effective temperature of the bluest model of the loop, the various assumptions for the amount of core and envelope overshoot, and the $^{12}C\ (\alpha, \gamma)^{16}O$ reaction rate. Chiosi *et al.* (1989) and Vallenari *et al.* (1990) adopted models computed with core overshoot alone at high efficiency (Λ=1.0) and metallicity Z=0.02, in which the He- to H-lifetime ratio is about 0.06 for the masses of interest. With the new opacities and the same value of Λ and metallicity, this ratio is about 0.05. The luminosity functions for the main sequence stars normalized to the post main sequence objects (e.g. Chiosi *et al.* 1989) got from models with the old opacities and high efficiency of core overshoot (Λ=1.0), or those derived from models with the new opacities and less efficient core overshoot (Λ=0.5), are both compatible with those observed by Chiosi *et al.* and Vallenari *et al.* However, only models with Λ=0.5 possess extended loops in

R. Haynes and D. Milne (eds.), The Magellanic Clouds, 327–328.

the H-R diagram (tracks (d), (e), and (f) of Table 1), while models with $\Lambda=1.0$ never develop extended loops, mainly because of the higher evolutionary rate during central He-burning (model (g) of Table 1). The extension of the loop, then, can be taken as a decisive morphological test against very efficient core overshoot, at least in the mass range corresponding to the stars in the blue loop of the young LMC clusters. Suitable models can be obtained assuming $\Lambda=0.5$. The effect of envelope overshoot can be understood looking at the various models given in Table 1. Model (d) of the $7M_\odot$ star is computed with envelope overshoot of 0.7 Hp and the lower $^{12}C\ (\alpha, \gamma)^{16}O$ rate, while models (e) and (f) are calculated with envelope overshoot of 1Hp and both the lower and higher $^{12}C\ (\alpha, \gamma)^{16}O$ rate. Models (d) and (f) of the $5M_\odot$ star possess envelope overshoot of 0.7 and 1Hp respectively and the lower $^{12}C\ (\alpha, \gamma)^{16}O$ rate. The results in Table 1 show that adding some overshoot at the base of the convective envelope does not alter the He- to H-burning lifetime ratio. Also, if efficient core overshoot is allowed, as for $\Lambda=1.0$ (model (g) of the $7M_\odot$ star), no extended loops are possible, even with large envelope overshoot or enhanced $^{12}C\ (\alpha, \gamma)^{16}O$ rate. To conclude, the new models of intermediate mass stars, which account for both core and envelope overshoot, not only predict the correct luminosity functions but also reproduce the morphology of real clusters, providing an advanced step with respect to classical models which only gave the correct morphology, but fail to predict the number of stars in the different phases across the HR diagram. A complete set of models, calculated with the assumptions outlined in this paper, will be published elsewhere (Alongi *et al.* 1990b).

Table 1. Main features of the $7M_\odot$ and $5M_\odot$ models computed for this work. See text for symbols.

$M = 7M_\odot$					
	t_H	t_{He}	t_{He}/t_H	$Teff_{(loop)}$	notes
a)	40.29	7.14	0.177	3.945	classical, CFHZ85.
b)	49.96	4.19	0.084	3.710	$\Lambda = 0.5$, CF88.
c)	49.96	4.07	0.081	3.821	$\Lambda = 0.5$, CFHZ85.
d)	49.96	3.81	0.076	3.952	$\Lambda = 0.5$, CF88, 0.7 Hp.
e)	49.96	3.84	0.077	4.016	$\Lambda = 0.5$, CFHZ85, 1.0 Hp.
f)	49.96	3.83	0.077	4.016	$\Lambda = 0.5$, CF88, 1.0 Hp.
g)	58.12	2.69	0.046	3.795	$\Lambda = 1.0$, CF88, 0.7 Hp.
$M = 5M_\odot$					
a)	80.16	20.01	0.250	3.846	classical, CFHZ85.
b)	101.61	8.98	0.088	3.717	$\Lambda = 0.5$, CF88.
d)	101.61	9.25	0.091	3.923	$\Lambda = 0.5$, CF88, 0.7 Hp.
f)	101.61	9.35	0.092	3.932	$\Lambda = 0.5$, CF88, 1.0 Hp.

lifetimes in units of 10^6 yrs.

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