THEORETICAL RED-GIANT BRANCHES FOR GLOBULAR CLUSTERS

Don A. VandenBerg
University of Victoria

VandenBerg (1983a; hereinafter V) has recently computed a large grid of stellar evolutionary sequences from the zero-age main sequence to the base of the red-giant branch (RGB) and carried out extensive comparisons of the associated isochrones with published photometry of globular clusters (GCs). These calculations were based on the latest Los Alamos opacities and, in addition, made use of available model atmospheres for improved surface boundary conditions as well as for the transformation of the stellar models from the (M_{bol}, log T_{eff})-to the (M_V, B-V)-plane. In general, very encouraging agreement of the predicted and observed morphologies of cluster C-M diagrams was obtained.

This paper reports the continuation of these published sequences from the base of the RGB to the helium flash. Representative models with masses in the range of 0.8 to 0.9 $M_\odot$ were selected in order that the stars on the giant branches had ages of approximately 16 billion yr, so as to have consistency with the GC age estimates made by V. Initial numerical experiments indicated that a value of α = 1.6 for the ratio of the mixing length to the pressure scale height was needed to provide the best match of the Z = 0.0001 model sequence with the observations of M92. Sequences for the other assumed metallicities, Z = 0.0003, 0.001, 0.003, and 0.006, were then computed for the same value of the mixing-length parameter and overlayed directly on the observations, which were transposed to the $[M_V, (B-V)_o]$-plane using canonical values of distance moduli and reddening (see V). The resultant comparisons are illustrated in Figure 1. The overall good agreement indicates that current model atmosphere and interior calculations are able to provide a remarkably faithful reproduction of observed giant branches. The slight discrepancies which do occur at the base of the metal-poor sequences and at the tips of the metal-rich sequences are within the existing observational and theoretical uncertainties. (For instance, the mean lines of M92 and M13 fainter than $M_V \sim 1.5$ are based on relatively few observations and the predicted colors and bolometric corrections of stars cooler than 4000 K are poorly understood.) Note that the observations of 47 Tuc have come out approximately centered between [Fe/H] = -0.5 and [Fe/H] = -0.8.

A. Maeder and A. Renzini (eds.), Observational Tests of the Stellar Evolution Theory, 143–146.

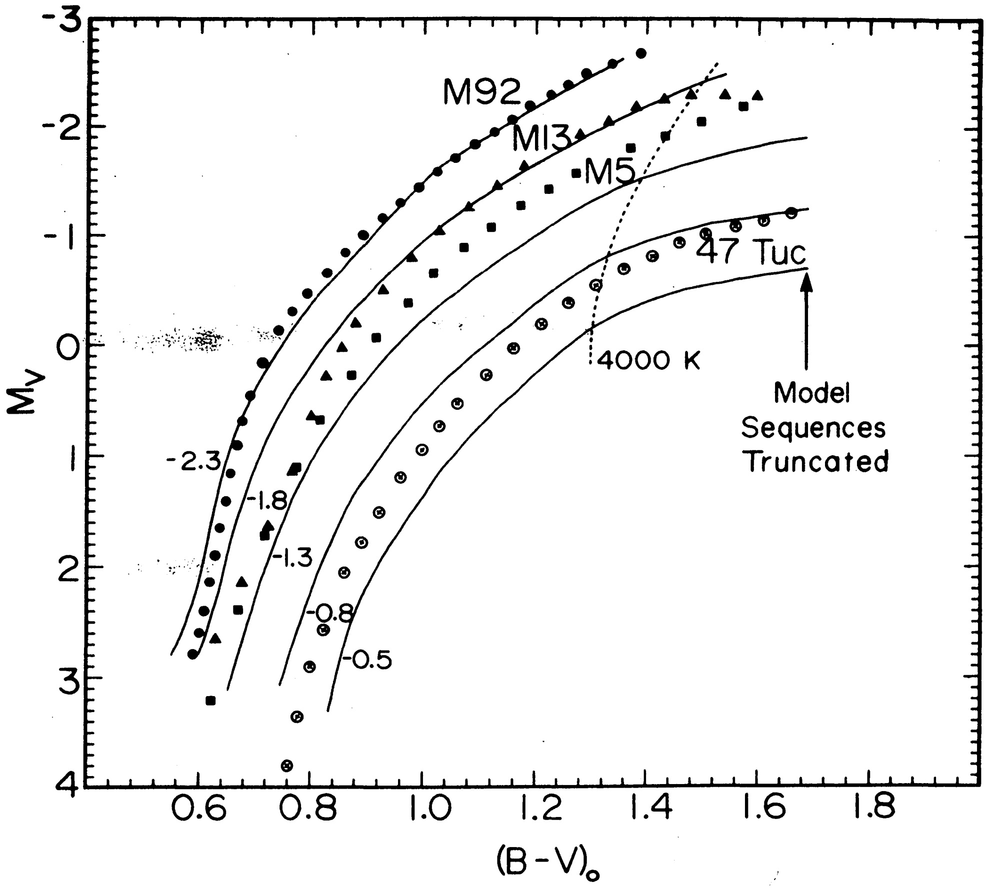

Fig. 1. - Comparison of computed model sequences (solid curves) with the mean giant branches (symbols) of four galactic globular clusters. Given at the lower left are the [Fe/H] values appropriate to the theoretical RGB's, which are based on model atmospheres for surface boundary conditions, colors, and bolometric corrections to the left of the 4000 K locus. Extrapolations of the atmospheric quantities were required for models predicted to have T_{eff} < 4000 K. Due to uncertainties arising from TiO absorption, model sequences were arbitrarily truncated at $(B-V)_o = 1.68$.

Figure 2 presents the same model sequences on the theoretical plane along with the fiducial loci for three globular clusters as derived by Frogel, Persson, and Cohen (1981; hereinafter FPC) using infrared photometry. Although the calculations assume Y = 0.2, similar good agreement of the models with the observations can be obtained for Y = 0.3 provided that α is reduced slightly. In any case, this work suggests that the mixing-length parameter must be nearly constant, having a value in the range of 1.45 < α < 1.65, in agreement with conclusions reached by V from main-sequence turnoff comparisons. We find good consistency between Figs. 1 and 2, particularly for M92 and M13, but less so for 47 Tuc. The latter should have been centered between Z = 0.003 and Z =

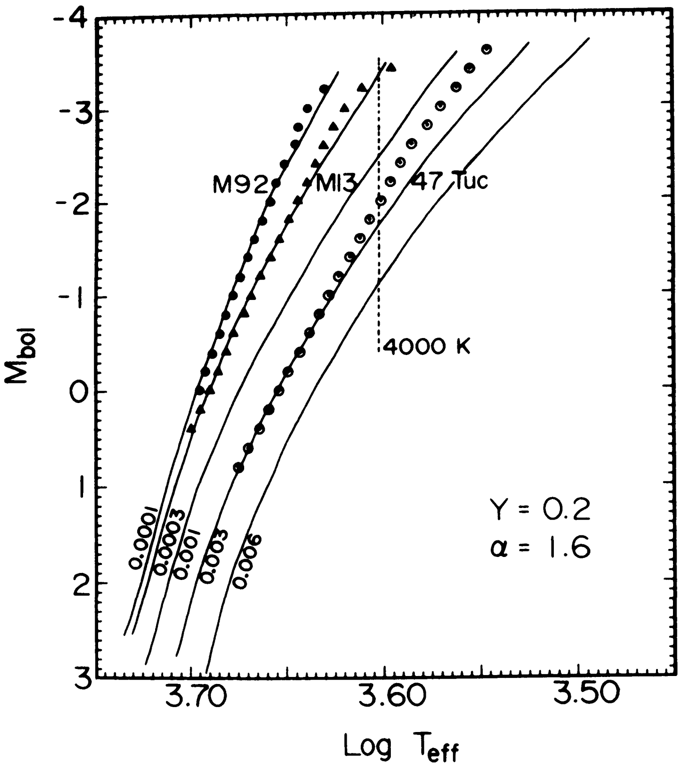

Fig. 2. - Comparison on the theoretical plane of the same model sequences shown in Fig. 1 (solid curves) with the mean lines (symbols) derived by FPC for M92, M13, and 47 Tuc.

0.006 (in Fig. 2) to be fully consistent with its location in Fig. 1, which may be suggesting that the B-V value at a given temperature (in the metal-rich regime) is underestimated by current model atmospheres. If this is the case, the models would tend to favor the possibility that the metallicity of 47 Tuc is closer to [Fe/H] = -0.8. The apparent discrepancy of about 150 K between the tip of the Z = 0.003 theoretical RGB and that of 47 Tuc reflects the present uncertainty in our understanding of the color-temperature relation for cool stars. A careful examination of that used by FPC suggests that their adopted relation is systematically too hot below $\sim$ 4000 K, which in turn would imply that the present models provide a more realistic representation of the temperatures of metal-rich giants (see VandenBerg 1983b).

REFERENCES

Frogel, J.A., Persson, S.E., and Cohen, J.G. 1981, Ap.J., 246, 842. (FPC)
VandenBerg, D.A. 1983a, Ap.J.Suppl., 51, 29. (V)
__________________. 1983b, in preparation.

https://doi.org/10.1017/S0074180900030722 Published online by Cambridge University Press

DISCUSSION

Mestel: You find that taking α = mixing length/scale height as a constant through a convection zone yields satisfactory results. Can you say how sensitive are the results to the actual value of α? Also, I recall that 25 years ago there was a question about whether one could simultaneously describe both type I and type II cluster giant branches just by metallicity variations, or whether different values of α are required.

VandenBerg: Changing α from 1.5 to 1.7, say, changes the predicted T_{eff} by $\gtrsim$ 150 K. Due to the steepness of the color-temperature relation for low gravity stars, the predicted B-V color is altered by nearly 0.1 mag; consequently large variations in α are almost certainly ruled out. Although I have not made detailed comparisons of isochrones with young Pop. I clusters, preliminary indications are that similar values of α ($\approx$1.5) also apply, so that cluster giant branches are indicative primarily of composition or age.