LETTERS TO NATURE

Helium Content of M 92 deduced from the Subgiant Luminosity Function

HARTWICK[1] has used the method of semi-empirical evolution due to Sandage[2], together with homologously transformed stellar models of Iben and Faulkner[3], to deduce that the helium content of M 92 is probably close to $Y=0.35$. This result was obtained by plotting the fuel consumed (expressed in terms of mass-fraction) against the bolometric magnitude, and comparing this theoretical quantity with the equivalent quantity deduced by the semi-empirical method. Good agreement was obtained for $Y=0.35$, but not for $Y=0.10$ or 0.01. The disagreement in the last two cases was particularly striking in the regions just above the turn-off point. As Hartwick noted, this was in part a reflexion of the fact, first pointed out by Simoda and Kimura[4], that the slope of the luminosity function φ in this region is extremely sensitive to the helium content. Indeed, this sensitivity was dramatically exhibited when Hartwick, on "unevolving" the M 92 data, found that the initial luminosity function would be required to decrease quite sharply to fainter magnitudes for $Y=0.10$ and 0.01, whereas it increased slightly for $Y=0.35$. The former behaviour is most unpalatable, but the latter is what one might expect on other statistical grounds[5].

At the time that Hartwick published his conclusions, Simoda and Iben[6] produced a very complete set of time-constant loci and theoretical mass-luminosity functions for metal-deficient clusters. These computations were more extensive than those of Iben and Faulkner, and used improved Cox–Stewart[7] opacities. It is therefore of interest to see what statements can be made about the helium content of M 92 on the basis of the newer models, particularly as the comparisons can now be made more directly.

The essential point is that the rate of luminosity evolution beyond the turn-off point accelerates at very different rates, depending on Y, before becoming comparable again once the giant branch proper has been reached. The slope of the luminosity function reflects this rate of acceleration. It should be emphasized that despite the uncertainties in model temperatures due to the well advertised deficiencies of theories of convection, most investigators are agreed that luminosity evolution is essentially independent of the convection treatment. The luminosity acceleration differs between the models of different Y primarily because of the different helium profiles, both *ab initio* and as established during the long main sequence phase.

If one studies the results of Simoda and Iben (particularly their Fig. 10), it is obvious that a maximum slope of φ is attained in the region between the turn-off and the giant branch, and that this may be used as an observational test. Confining attention to this region, one finds the results shown in Table 1, where the uncertainties are occasioned solely by the computed age spread (ages are in the range $\sim 9\times 10^9$ yr to $\sim 24\times 10^9$ yr).

Table 1 Relation at Maximum Slope φ to Helium Content Y

	$Y=0$	$Y=0.2$	$Y=0.35$
$\dfrac{\Delta \log \varphi_{SI}}{\Delta M_{Bol}}$	1.9 ± 0.4	1.05 ± 0.2	0.7 ± 0.1

From Hartwick's work we find the same region gives the observational result

$$\frac{\Delta \log \varphi_H}{\Delta M_v} = 0.74 \qquad (1)$$

As considerations of differential bolometric corrections can only serve to reduce Hartwick's value, the above results would seem, on the face of it, to constitute *prima facie* evidence for a high helium content. The changes due to differential bolometric corrections are no larger than the theoretical uncertainties given above. If we ignore their effect, we obtain

$$Y\sim 0.33\pm0.05 \qquad (2)$$

a result in good agreement with that derived by somewhat lengthier and less direct means[8]. Further supporting evidence follows from the fact that the giant branch shows a smooth departure from the steeper part of the log $\varphi_H - M_v$ plot after $\sim$1.2 magnitudes, in good agreement with the log $\varphi_{SI} - M_{Bol}$ theoretical plot for $Y=0.35$ and in marked contrast with the sharper departure after only $\sim$0.8 mag ($Y=0.2$) and $\lesssim$0.4 mag ($Y=0.0$). It is indeed salutary to realize that early post-main-sequence evolution yields such powerful conclusions, emphasizing once again the importance of accurate work with large telescopes at the turn-off point of globular clusters.

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Long-term Intensity Variations of Pulsars observed at Two Frequencies

PULSARS are known[1,2] to exhibit irregular intensity variations with time-scales of weeks and months. For pulsars CP 0808, CP 0834 and CP 1919 the observations have been continued at 81.5 MHz and extended to 151 MHz. A comparison of the daily intensities at the two frequencies has established that they are correlated.

The receiving system at 81.5 MHz consisted of the 4 acre array and a total power receiver with a bandwidth of 200 kHz and a time constant of 20 ms. At 151 MHz the system comprised the large element of the 4C aerial and a phase-switching