THEORETICAL EVIDENCE OF MASS LOSS FROM GLOBULAR CLUSTER STARS

V.Castellani and A.Tornambè
Istituto di Astrofisica Spaziale, Frascati

SUMMARY: The total amount of mass lost during the first giant phase of Population II red giants is derived from Horizontal Branch properties: it is found to be proportional to the metal content.

Some constraints on the total amount of mass lost during the first red giant evolution may be derived from the immediately following evolutionary phase: the Horizontal Branch (HB). The location of a star on the HB is drastically dependent (mainly in the color, but also in the luminosity) from its mass. Unfortunately, also the chemical composition, i.e., Y, Z and Z_{CNO}, plays a fundamental role in determining the location of a horizontal branch star in the HR diagram. Moreover, once determined the mass of a HB star, the mass of main sequence stars (through the age and chemical composition of the cluster) must be known, to derive the amount of the mass lost during the RG phase. Other observational constraints that need to be fitted besides the HB morphology help in reducing the number of free parameters eventually to zero. The constraints we used in playing this game are the following: (i) the RR-Lyrae variables, whose properties (mean periods, period frequency histogram PFH, ratio of ab to c pulsators, minimum and maximum periods ....) indirectly depend on chemical composition; (ii) the difference in luminosity between the HB and the turn-off, which, if the composition is known, is a measure of the cluster age; (iii) the fact that we have about 20 clusters rich of RR-Lyrae variables, which have to be placed correctly in the final scheme, if self-consistent.

We computed a large number of synthetic HB and PFH (evolutionary effects included) varying Y, Z and the mean HB mass. I cannot discuss here the details of this work which are widely explained elsewhere (Castellani and Tornambè, 1980); the main results are the following:

i) All the RR-Lyrae rich clusters may be understood assuming a helium abundance of 0.23 and an age of $\sim$12 Gyrs, the metal content being the one observed (revised metallicities by Caputo and Di Gregorio, 1980);

ii) the HB masses range between 0.82 $M_\odot$ when $Z\sim10^{-4}$ and 0.7 $M_\odot$ when $Z\sim10^{-3}$;

C. Chiosi and R. Stalio (eds.), Effects of Mass Loss on Stellar Evolution, 357–359.
Copyright © 1981 by D. Reidel Publishing Company.

https://doi.org/10.1017/S0252921100095026 Published online by Cambridge University Press

iii) the family of the RR-Lyrae rich clusters nicely fits also other observed properties, like the puzzling Oostherhoff dycotomy.

To achieve this agreement, we were forced to rise by 6% the evolutionary core masses at the beginning of HB phase. This requirement is not surprising, if one remembers that stellar rotation and neutral currents, which do exist, rise the core masses (see also the answer to Iben's question).

We know from the theory that if y=0.23 and the age is t_9=12, the star undergoing the He flash had a mass of 0.9 $M_\odot$ in the main sequence phase (this value depends very little on the metal content). This means that the total mass loss ranges between ∿0.1 $M_\odot$ when Z∿ 10^{-4} to ∿0.2 $M_\odot$ when Z∿10^{-3}.

Although this scheme seems consistent with observations it suffers from the assumption of a solar CNO/Fe ratio. We know (Castellani and Tornambè, 1977; Rood, 1980) that increasing CNO in HBs means to shift the star toward the red; as a consequence, HBs with increased CNO, but with the same morphology of a standard CNO horizontal branch, will be explained with lower masses than the standard one. When CNO/Fe abundances will be knwon for a larger amount of clusters, this scheme might be modified if the CNO will be found to be non solar. The important result is, however, that we have the possibility of putting strong limits to the mass loss rates, which any theory of mass loss must satisfy.

REFERENCES

Caputo, F., Di Gregorio, R.: 1980, Internal Report n. 33 of the Istituto di Astrofisica Spaziale.
Castellani, V., Tornambè, A.: 1977, Astron. Astrophys. 61, 427.
Castellani, V., Tornambè, A.: 1980, Astron. Astrophys., in press.
Rood, R.T.: 1980, Private communication.

https://doi.org/10.1017/S0252921100095026 Published online by Cambridge University Press

DISCUSSION

IBEN: Some years ago, models suggested that, for Helium abundances as low as Y = 0.23, ages in excess of 15 - 18 x 10^9 yr were to be expected. What has changed to permit ages as small as 12 x 10^9 yr.

TORNAMBE': I have not mentioned it, but you may find exposed in the written paper that to reach the agreement I found between observations and theory I was compelled to rise the He-core mass of 6% at the beginning of HB phase. This makes the HB overluminous with respect to the standard y= 0.23 HB thus affecting the age determination based on the luminosity difference between turn off and HB. It is remarkable that the increase of 6% of He core mass is well inside the indeterminacy of the models. If you take into account the larger neutrino flux due to the neutral currents and a bit of rotation (standard 1.8 x 10^{-4}r/sec in M. S.) you can easily increase the core of 4%.

SERRANO: The result you have found is self-consistant in terms of stellar evolution in general. Since from Y of ejected matter and the present Y you can obtain again Y_p (pregalactic). If you use these HII regions results you also get Y_p = 0.23. At this value the standard big bang is already in trouble. It is thus an extremely important result.

https://doi.org/10.1017/S0252921100095026 Published online by Cambridge University Press