Variable Blue Stragglers and the EASE Scenario

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Abstract. Variable blue stragglers have been shown to be reliable distance indicators for globular clusters (McNamara, 2001). Their location in the HR diagram suggest however that they are either binaries or the results of mergers of two stars. This can indeed explain the apparent differences in the ages of blue sttragglers and those of globular clusters.

We show that this location can also be explained in some cases by single low mass stars having a chemical composition nearly devoided of metals. This would be in agreement with the EASE scenario (Jehin et al. 1999) for the formation of globular clusters.

Keywords: Blue Stragglers, Globular Clusters

1. Introduction

Using high amplitude δ Scuti variables (HADS) as distance indicators, McNamara (2001) inferred the absolute magnitude of the main sequence turnoffs in 16 globular clusters. The *P*-*L* relation gives the absolute visual magnitude of an HADS whose period is *P*. This in turn gives the distance modulus of the globular cluster and hence the absolute magnitude of the turnoff stars. The mean age determined by McNamara (2001) is 11.3 ± 1 Gyr in good agreement with various other theoretical isochrone fittings. This means, as it is now generally admitted, a rather small value of the age as well as a weak dispersion.

These HADS have effective temperatures which are typical of blue stragglers. Assuming a metallicity similar to that of the globular cluster itself, their ages can be determined through their Period-Luminosity relation and their effective temperatures. The results show them much younger than the globular clusters in which they are embedded. This favours the assumption of a blue straggler being the result of a merger of two stars.

On the other hand, the EASE scenario (Jehin et al., 1999), which links halo stars to globular clusters, foresees the presence of some extremely metal-poor stars in all the globular clusters. Using this assumption on their metallicity, some of the variable blue stragglers are found much older, with an age comparable to that of the globular clusters.

2. Age Determination of HADS in Globular Clusters

The HADS stars in globular clusters are located at higher luminosity and higher effective temperature than the turnoff stars which makes them more massive and apparently younger. For a given chemical composition ($Z = 0.005$), that of a given globular cluster, we have computed evolutionary tracks for various values of the mass. For each model, the period of the fundamental mode of radial pulsations is then derived, leading to a $(\log P, \log T_e)$ diagram. Knowing the age of each model, these theoretical data can be transformed into an (age, $\log P$) diagram. Such diagrams directly allow an age determination through the knowledge of the period and the metallicity $[Fe/H]$. Such a method has been proposed by Andreasen et al. (1983). We find ages generally much smaller than the globular clusters', as can be expected.

3. Blue Stragglers

The HADS in globular clusters are generally hotter and more luminous than the turnoff stars, which puts them in the HR diagram in the region of blue stragglers. The apparent discrepancy between the evolutionary state of such stars, more massive than the turnoff stars but still in their core hydrogen burning phase, has led to numerous suggestions as to their real nature (see for example Mateo, 1996). It is now generally admitted that they are produced by a binary system, either containing two close but distinct stars still in their main sequence phase, or having merged into a more massive main sequence star. If such a merging has taken place, the age determination described in Section 2 makes sense but the age is the time interval since the merging and has therefore no relevance to the age of the globular cluster itself.

4. EASE Scenario

Some puzzling behaviours in the heavy element abundances in metal poor stars have led Jehin et al. (1999) to imagine a scenario which on the one hand, separate halo stars into two groups of stars, namely PopIIa and PopIIb stars, and on the other hand, closely links halo stars to globular clusters. This scenario, named EASE (Evaporation, Accretion, Self-Enrichment) describes the early phases of a globular cluster as two-fold. At the very beginning, a first generation of (mostly) massive stars is formed in the proto-globular cluster cloud. These stars are (nearly) metal free. The most massive ones rapidly evolve into SNII explosions, which enrich the remaining interstellar matter. The proto-globular cluster either is disrupted by these explosions and the residual stars form PopIIa stars, or resists the explosions and a second generation of stars forms in the metal enriched matter. Some of these stars can then accrete matter from AGB winds, evaporate from the cluster and become PopIIb stars.

According to this scenario, some nearly metal free stars could still be hidden in every globular cluster. They would be the same age than the cluster but would differ drastically in metallicity, especially for the more metal rich globular clusters. They would also, at the present time, cover about the same mass range than the second generation of stars (although with a different IMF).

However, it is well known that a smaller metallicity moves the evolutionary tracks towards higher effective temperatures and slightly higher luminosities. The turnoff of these first generation stars would then be located inside the blue stragglers region of the HR diagram.

5. Age Determination of HADS in the EASE Scenario Framework

With this scenario in mind, we have computed evolutionary tracks for $Z = 0.00001$ and we have transformed them into a $(\log P, \log T_e)$ diagram and an (age, $\log P$) diagram. Whatever the chemical composition of the globular cluster, we have assumed that at least some HADS were residual stars from the first generation, that is stars with a close to zero metallicity and we have derived their age.

For most of the variable stars, there is now an agreement between their age and the globular cluster's. *Our suggestion is thus that some of the variable stars and/or blue stragglers in globular clusters are first generation stars.* Those which still show a discrepancy are probably “ordinary" variable blue stragglers resulting from the merger of two stars.

Figure 1 show the globular cluster $M53$ on which we have superposed two isochrones of the same age (12 Gyr) and for two different chemical composition each $(Z = 0.0005$ and $Z = 0.00001)$. The close to zero metallicity isochrone nicely fits the lowest part of the blue straggler region while the cluster metallicity isochrone fits the turnoff cluster. However, some of the blue stragglers, especially the hottest ones, cannot be first generation stars.

6. Conclusions

In the framework of the EASE scenario, some HADS stars in globular clusters could be residual stars from the first generation of stars in the early phases of a globular cluster formation. The more metal rich the globular cluster is, the larger the interval in effective temperature between the “normal" turnoff stars and the “first generation" turnoff stars is, making them blue stragglers. For

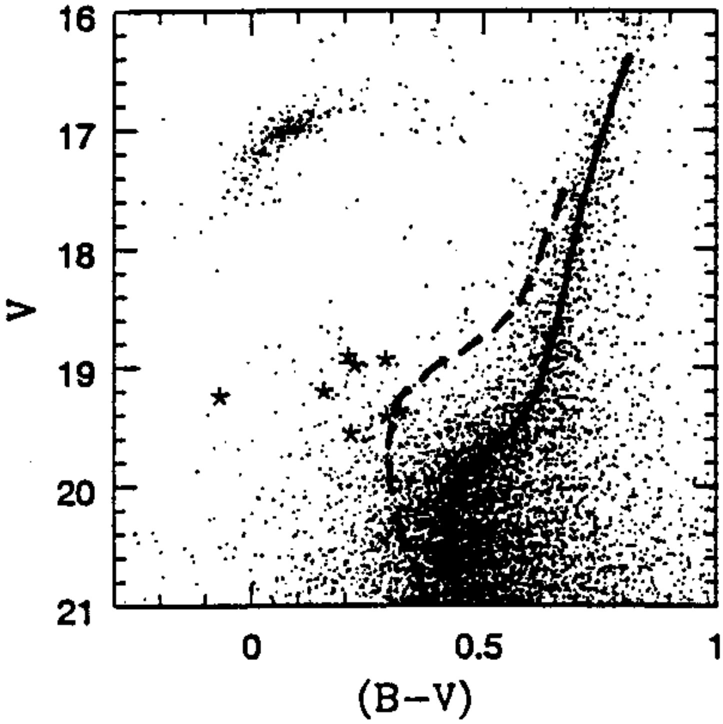

Figure 1. Colour-Magnitude diagram for the globular cluster *M*53. Isochrones of 12 Gyr have been superposed. The full line one is computed with a metallicity $Z = 0.0005$ while the dotted line one is related to first generation stars with $Z = 0.00001$.

very metal poor globular clusters, the difference in $\log T_e$ is negligible and the first generation stars are embedded in the “normal" turnoff stars.

References

Andreasen, G.K., Hejlesen, P.M. and Petersen, J.O.: 1983, *A&A* **121**, 241.

Jehin, E., Magain, P., Neuforge, C., Noels, A., Parmentier, G. and Thoul, A.A.: 1999, *A&A* **341**, 241.

Mateo, M.: 1996, in: E.F. Milone and J.-C. Mermilliod (eds.), *The Origins, Evolution and Destinies of Binary Stars in Clusters*, *ASP Conf. Ser.* **90**, 346.

McNamara, D.H.: 2001, *PASP* **113**, 335.