Mem. S.A.It. Vol. 84, 101
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Memorie della

The asymptotic giant branches of GCs: selective entry only

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Abstract. The limited observations of AGB stars in Galactic Globular Clusters (GCs) suggest that the GC AGB populations are dominated by cyanogen (CN) weak stars. This contrasts with the distributions in the RGB (and other) populations, which generally show a 50:50 bimodality in CN. If it is true that the AGB populations show different distributions then it presents a problem for low mass stellar evolution theory, since such a surface abundance change going from the RGB to AGB is not predicted by models. However this is only a tentative conclusion, since it is based on small AGB samples. To test whether this problem is real we have carried out an observational campaign targeting AGB stars in GCs. We obtained medium resolution spectra for 250 AGB stars across 9 GCs using 2df/AAOmega on the AAT. We present some preliminary findings for the second parameter trio of GCs: NGC 288, NGC 362 and NGC 1851. The results indeed show that there is a deficiency of stars with strong CN bands on the AGB. To confirm that this phenomenon is robust and not just confined to CN band strengths and their vagaries, we have made observations using FLAMES/VLT to measure elemental abundances for NGC 6752. Our VLT sodium abundance results show conclusively that only a subset of stars in GCs experience the AGB phase of evolution. This is the first concrete confirmation of the phenomenon.

Key words. AGB stars – Globular cluster – Abundances – Cyanogen

1. Introduction

One of the first chemical inhomogeneities discovered in Galactic globular clusters (GCs)

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was that of the molecule cyanogen (CN, often used as a proxy for nitrogen; eg. Norris et al. 1981). The CN band strengths show strong star-to-star variations, with the populations falling into two (or more) populations: CN-weak stars and CN-strong stars. This CN bimodality is seen in all evolutionary phases studied in detail thus far.

Due to the paucity of asymptotic giant branch (AGB) stars in GCs (a result of their short lifetimes), plus the difficulty in splitting the red giant branch (RGB) and AGB in colour-magnitude diagrams (CMDs), there have been very few systematic observational studies of the CN anomaly in the AGB populations of globular clusters (Mallia 1978 is one of which we are aware). What little that has been done has been an aside in more general papers (e.g. Norris et al. 1981, Briley et al. 1993, Ivans et al. 1999, Sneden et al. 2000). However these studies have hinted at a tantalising characteristic: most (observed) GCs show a lack of CN-strong stars on the AGB. If this is true then it is in stark contrast to the RGB and earlier phases of evolution, where the ratio of CN-Strong to CN-Weak stars is roughly 50:50 in many clusters. It is also strange from a stellar evolution theory perspective, since a surface abundance change going from the RGB to AGB is not predicted by standard models. The possible existence of this phenomenon is however based on studies with small sample sizes.

Here we present some preliminary results of our large study that increases the GC AGB sample sizes substantially. With this new information we hope to confirm or disprove the existence of the abundance differences between the AGB and other phases of evolution.

2. Observations: CN band strengths

A vital ingredient in being able to find significant numbers of AGB stars in globular clusters is having photometry good enough to separate the AGB from the RGB. For the current study we have used the Walker (1992) sample for NGC 8151, plus a range of other CMDs, mostly from Grundahl et al. (1999). In total our sample consists of a database of $\sim$ 800 stars at various stages of evolution (RGB, HB & AGB), in 10 GCs.

The medium-resolution observing run consisted of 5 nights on the AAT. We used the multi-object spectroscope, AAOmega/2dF Smith et al. (2004). On the blue arm we used the 1700B grating, which gave a spectral coverage of 3755 to 4437 Å, which includes the violet CN bands. The resolution of the spectra is $\sim$ 1.2Å. Near the CN bands the S/N $\gtrsim$ 20.

To quantify the CN band strengths in each star we use the S(3839) CN index of Norris et al. (1981). We then remove the trend with temperature (see Norris et al. 1981; Campbell et al. 2012), finally giving the δS(3839) value.

3. Intriguing results: CN distributions and HB morphology

In this conference proceedings we present preliminary results for the second parameter trio NGC 288, NGC 362 and NGC 1851. These GCs all have similar metallicities ([Fe/H] ~ -1.3) but different HB morphologies (blue, red and blue+red HBs respectively; Bellazzini et al. 2001).

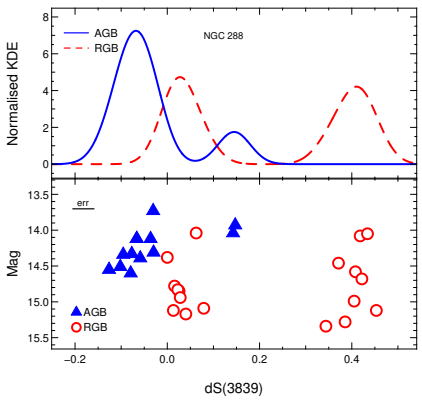

Fig. 1. Preliminary CN results for NGC 288 from AAT/2dF. Lower panel shows the δS(3839) results for each of the stars in our sample. The upper panel shows the same data represented by a kernel density estimate histogram (kernel bandwidth = 0.035).

In Figure 1 we show the δS(3839) results against magnitude for NGC 288. This GC shows the classic bimodality in CN on the

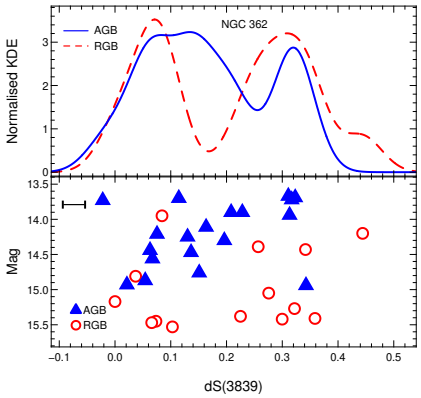

Fig. 2. Same as Fig. 1 but for NGC 362.

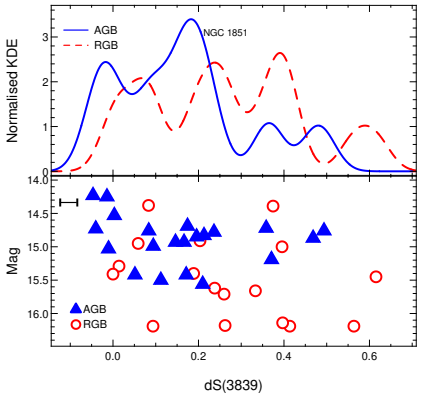

Fig. 3. Same as Fig. 1 but for NGC 1851.

RGB. However the AGB is clearly dominated by CN-weak stars. This is a very large change in CN population proportions, especially considering that all other phases of evolution show similar ratios to the RGB. Interestingly there is a hint of bimodality on the AGB also, with two stars being significantly more CN-strong than the other AGB stars (although still considered CN-weak compared to the RGB stars). In Figure 2 we show the δS(3839) results against magnitude for NGC 362. Again the classic bimodality can be seen in the RGB. However the AGB results are less clear. We suggest that the AGB CN distribution is consistent with there being no change in proportions between the RGB and AGB. A comparison of the NGC 288 and NGC 362 results suggest that the abundance anomalies are related to HB morphology, such that GCs with blue HBs show a lack of CN-strong stars on the AGB whilst GCs with red HBs do not. Finally, in Figure 3 we show the δS(3839) results against magnitude for NGC 1851. This GC has a combination of a red and a blue HB, so could be considered an intermediate case between NGC 288 and NGC 362. The RGB results are quite different to the other GCs – the distribution appears to be quadrimodal. This is lent more weight by the AGB distribution, which is also quadrimodal, although the majority of the stars are CN-weak. We have discussed this interesting case elsewhere in the context of a GC merger scenario (Campbell et al. 2012).

4. Conclusive proof: high-resolution elemental abundances

The preliminary results of our CN study strongly support the unexpected phenomenon in which CN-strong stars seem to 'disappear' between the RGB and AGB, leaving CN-weak dominated AGBs. However there is the possibility that the measurements of CN in AGB stars are biased in some way, either by gravity or temperature differences as compared to the RGB stars. Cyanogen molecular band strengths are also affected by the distribution of C, N and O. For these reasons the CN results are not considered 100% robust. In order to conclusively determine the proportions of polluted and non-polluted stars on the AGB we have undertaken a high resolution study of NGC 6752 using VLT/FLAMES. In Campbell et al. (2010) we reported our preliminary CN results for NGC 6752. This cluster is similar to NGC 288 (Fig. 1), showing a clear bimodality in the RGB sample and a CN-weak dominated AGB. In Figure 4 we show our preliminary VLT/FLAMES results for sodium in NGC 6752 AGB stars. A striking result can be seen – *every single AGB star is Na-poor*. This compares with a ratio of roughly 60:40 CN-strong to CN-weak in the RGB and other populations. It now appears certain that second-generation (N and Na-rich, C and O-poor stars) do not evolve to the AGB phase in NGC 6752, and probably many other GCs.

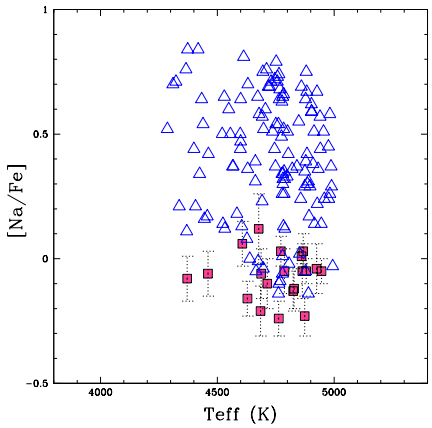

Fig. 4. Preliminary Na results from VLT/FLAMES spectra for our NGC 6752 AGB sample (red squares with error bars). Sodium for RGB stars from Carretta et al. (2007) are shown for comparison (open triangles).

One explanation for this phenomenon is that the two populations in NGC 6752 have different He abundances in addition to their C, N, O and Na abundance differences (Norris et al. 1981; D'Antona et al. 2002). The He-rich material would also be N-rich due to CNO cycling. The He-rich stars would then evolve to populate the bluest end of the HB – and not ascend the AGB – leaving only CN-weak stars to evolve to the AGB. This ties in well with the recent findings of Villanova et al. (2009) and Marino et al. (2011) (in NGC 6752 and M4 respectively) that the Na-rich stars populate only the blue ends of the HBs, whilst the Na-poor stars populate the red(der) ends of the HBs. The Na results for NGC 6752 presented here represent the first conclusive proof that only certain stars make it to the AGB phase of evolution – the other stars must go directly to the white dwarf phase.

Acknowledgements. Thanks to the LOC & SOC of of the conference held at Rome Observatory.

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