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The RGB Bump in dwarf Spheroidal galaxies: discovery and perspectives.

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Abstract. I report on the recent discoveries of the Red Giant Branch Bump(s) in many dwarf Spheroidal galaxies of the Local Group. The perspectives for the use of this new observational feature to obtain constraints on the Star Formation History and Age-Metallicity Relation of nearby galaxies are shortly explored and reviewed.

Key words. Dwarf Galaxies – Red Giant Branch stars – Luminosity Functions

1. Introduction

The so-called Red Giant Branch (RGB) bump is an evolutionary feature predicted by the theoretical models of the evolution of low-mass stars (Iben 1968). The H-burning shells moves away from the core of the stars during the evolution along the RGB. In its outward trip in search of fresh nuclear fuel the shell encounters the chemical discontinuity left behind by the maximum penetration of the convective envelope. At this time the luminosity of the stars drop for a while, until the shell adapts to the new environment, and then it rises again, burning in a regime of constant H content. As a result the star passes three times for the same short portion of the RGB evolutionary path, hence the evolutionary rate significantly slows down in this phase. As a consequence, at the RGB bump level the stars of a Simple Stellar Population (SSP, e.g. a population of coeval and chemically homogeneous stars) pile up, producing a bump in the Luminosity Function (LF).

From the observational point of view, the first detection of the RGB bump in a globular cluster (GC) dates back to the '80 (King et al. 1984). At the present time the bump has been observed in several tens of GCs, the detection technique is quite established (Fusi Pecci et al. 1990) and the luminosity of the bump is well predicted by theoretical models (see Zoccali et al. 1999; Ferraro et al. 1999,hereafter F99, and references therein).

Only very recently single and double RGB bumps have been detected in dwarf spheroidal galaxies (dSph) (Majewski et al. 1999; Bellazzini et al. 2001; Monaco et al. 2002; Bellazzini et al. 2003a), a fact that was somehow unespected given the nature of composite stellar populations (CSS, e.g., containing a mixture of stars of different ages and

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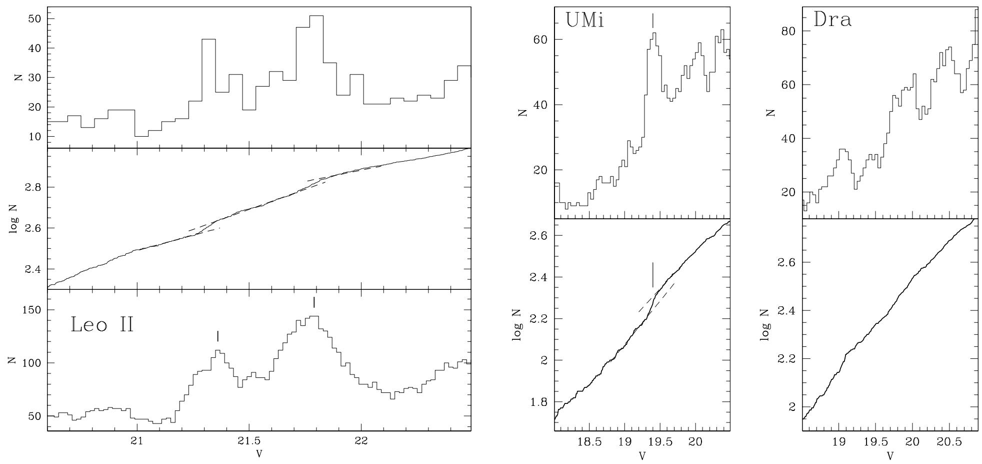

Fig. 1. Left panel: detection of a double RGB bump in Leo II. Central panel: the single RGB bump detected in UMi. Right panel: no significant bump is detected in the LF of Draco. The change of slope in the cumulative LF is the key indicator for the safe detection of the bump (Fusi Pecci et al. 1990).

metallicities) of these stellar system. Here we shortly report on the observational results in this field and provide some clues on the possible application of this new observable in the study of CSS.

2. The RGB bump in dSph galaxies

Majewski et al. (1999) reported the detection of two distinct RGB bumps in the Sculptor dSph. They interpret such double detection, together with the peculiar Horizontal Branch (HB) morphology, as evidence for the presence of two main populations (both quite old) having different metallicities. A very similar occurrence was found in the Sextans dSph by Bellazzini et al. (2001) and it was interpreted in an analogous way. In both the above cases the signal of the bumps in the LF is quite weak and the statistical significance of the observed peaks may be questioned. In the left panel of Fig. 1 a clear (and strongly significant) detection of a double bump in the Leo II is presented, as recently obtained by our group (Bellazzini et al. 2003b). This result proofs beyond any doubt that double bumps do occur in the RGB-LF of real galaxies (see also Sect. 3, below).

Single RGB bumps have been clearly detected in the Sgr dSph (Monaco et al. 2002) and in Ursa Minor, while the RGB LF of Draco doesn't show any significant bump (Bellazzini et al. 2003a,see Fig. 1). Thus the present observational scenario provides cases of *no bump*, *single* and *double bumps*, a remarkable variety considering that the searched sample is presently limited to six dSph galaxies.

The luminosity of the RGB bump of a given population depends on its metal content and on its age, hence the bumps observed in dSph's may possibly provide interesting constraints on their Star Formation History (SFH) and Chemical Enrichment History (CEH). We plan to study the behaviour of the RGB bump in composite population by means of extensive simulations of CSPs under different assumptions about SFH and CEH. Only such a detailed analysis would provide the necessary guidelines for a correct interpretation of the bumps observed in CSPs. Preliminary toy models suggests that a detectable bump may be originated either by (a) a relatively short ($t_{SF} \leq$

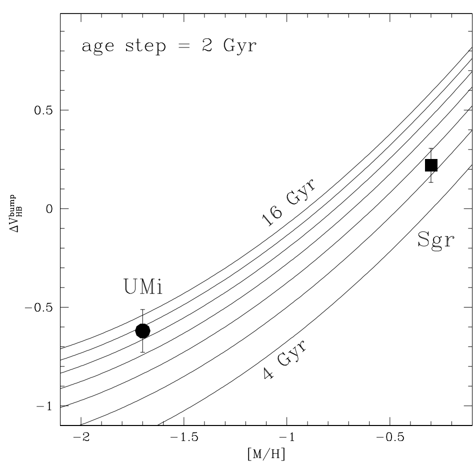

Fig. 2. The difference between the magnitude of the bump and that of the ZAHB is plotted versus the global metallicity for the UMi and Sgr dSph's. The continuous lines are isochrones from Eq. 3 and 4 by F99. Both galaxies are dominated by a main population well characterized in metal content and age, but the respective SFHs are much different. UMi produced the large majority of its stars at early epochs and low metallicity while the main star formation episode in Sgr occurred much later, when the chemical enrichment of the galaxy was in a quite advanced stage.

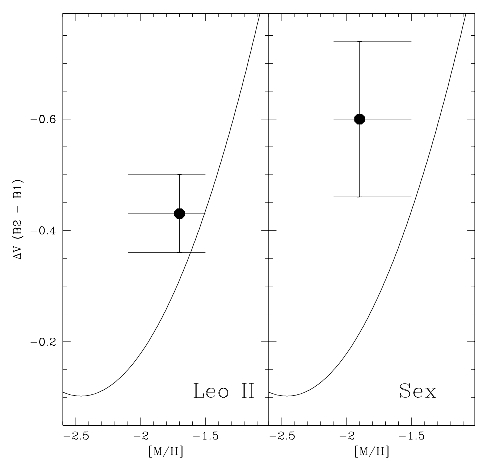

Fig. 3. The difference in magnitude between the brigther bump (B2) and the fainter bump (B1) for Leo II and Sex is compared to the expected difference between the AGB and the RGB bumps as a function of metallicity, according to the relations given by F99. The horizontal error bars cover the whole range of the possible values of [M/H] for the population associated to the main bump (B1).

2 Gyr) and intense star formation episode, or by (b) a relatively long (t_{SF} ∼ 4 Gyr) period of star formation associated with a low rate of chemical enrichment. The latter case is not surprizing since the luminosity of the bump is much more sensitive to metal content than age. The above results suggest that the luminosity of the RGB bump (as well as its *shape* on the RGB-LF) may ultimately provide very useful clues on the Age-Metallicity relation of a galaxy, in particular at old ages. At present, the best exemple of the use of the RGB bump as an independent tool to constrain the SFH of a dSph is probably the study of Sgr by Monaco et al. (2002) (see also Monaco, this meeting). A comparison with the case of Ursa Minor is presented in Fig. 2.

3. Contamination by the AGB bump?

Many colleagues, also at this meeting, expressed the doubt that the cases of *double* bumps (at present Scu, Sex and Leo II) may be due to a misinterpretation of the brighter bump (B2) that may be in fact the AGB bump of the population that generated the main (fainter) bump (B1) instead of a second RGB bump. The detailed analysis of this hypothesis is in progress. Nevertheless there are already serious arguments against this possibility. First, if this was the case we should have detected a double bump in any of the galaxies in which we found a RGB bump and this is in contrast with the observations for UMi and Sgr (note that Sgr is the case with the highest statistical significance). Second, in observed SSP in which the AGB bump can be easily identified, the number of stars in the peak of the RGB bump is ∼ 2 times larger than in the AGB bump. In all the double-bump cases the ratio of the number of stars in the LF peaks associated to B1 and B2 is ~ 1. This means that the signal (number of stars) expected for the AGB bump is much lower than what it is observed in all the B2 bumps detected to date. Finally, in Fig. 3 we compare the observed magnitude difference between B2 and B1 for Leo II and Sex, with the expected magnitude difference between the AGB and RGB bumps as a function of metallicity (from Eq. 6 and 7 by F99). In both cases B2 is significantly brighter than the expected AGB bump and the observed difference can be (marginally) reconciled with the *AGB bump hypothesis* only assuming rather unlikely average metallicity (Shetrone et al. 2001).

Therefore AGB bumps are very unlikely canditates for B2 and double bumps are probably both bona-fide RGB bumps. Assuming that the B2 bumps are associated with the most metal poor populations observed in the considered dSph's, the double bump feature suggest that in these galaxies the SFH at early epochs was somehow structured in different main episodes (see Bellazzini et al. 2001).

4. Conclusions

The recently discovered RGB bumps of dSph galaxies are a promising new tool for the study of the SFH and the AMR of composite stellar systems. These features are particularly sensitive in the old age regime where the time resolution of the Main Sequence Turn Off (MSTO) is rather low (and hard to exploit in CSPs), therefore they can be nicely complemetary to the traditional age indicators.

A preliminary exploration of the possible use of the bump as an age indicator for GCs whose MSTO is out of the reach of the present observational facilities also provided quite encouraging results. To exploit the full potentiality of the bump as an age indicator, accurate estimates of the global metallicity (e.g., $[M/H]$ which includes also the contribution of α-elements) are required. Such measures are now within reach of high-resolution spectrometers at 8-meters-class telescopes (e.g., HIRES, FLAMES) also for external galaxies and will be the subject of great observational effort in the next few years.

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