Horizontal Branch Morphology Gradients in Local Group Dwarf Spheroidals

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Abstract

In the last few years, for several Local Group dwarf galaxies radial gradients in the horizontal branch morphologies where found. We present a homogeneous analysis of spatial variations of different He-burning populations for a sample of nearby dwarf galaxies. Implications to the importance of environmental effects on star formation histories will be discussed.

1 Introduction and data

Most of the dwarf spheroidals (dSph) of the Local Group exhibit prominent old ($\geq$ 10 Gyr) populations indicated by the existence of a horizontal branch (HB). The HB often shows a bimodal morphology. An important parameter governing HB morphology is metallicity. Age on a several Gyr time scale is a leading second parameter candidate: Younger populations tend to form a redder HB (RHB), while old populations exhibit a blue HB (BHB), for the same metallicity (Lee, Demarque, & Zinn 1994).

We analyze the radial distribution of the red and blue HB in selected Local Group dSphs for which sufficient data is available: Three Milky Way companions (Carina, Sextans, and Sculptor), five Andromeda dSphs (Andromeda I–III, V, VI), the dSph/dIrr transition-type object Phoenix, and the isolated dSph Tucana. We also analyzed the distribution of red clump (RC) stars where present. The RC traces populations with ages of $\sim$ 1 Gyr to 10 Gyr.

Carina and Sextans were observed with the CTIO 4m Mosaic 2 camera, while Sculptor was observed with the BTC camera at the same telescope (Hurley-Keller, Mateo, & Grebel 1999). The data for the other galaxies were taken from the HST archive (see also Da Costa et al. 1996; 2000; Holtzman et al. 2000).

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Galaxy	Tidal radius [′]	Covered radius [′]	K-S (BHB/RHB)	T_2 (BHB/RHB)	K-S (RHB,RC)	T_2 (BHB,RC)
Carina	28.8	25	70 %	0.24	0.01 %	3.9
Sculptor	76	30	$3 \cdot 10^{-6}$ %	9.8	—	—
Sextans	160	40	0.8 %	2.6	—	—
Andromeda I	1.25	2	7 %	1.7	—	—
Andromeda II	1.7	2	10.8 %	1	—	—
Andromeda III	2.0	2	77 %	0.1	—	—
Andromeda V	n/a	2	18 %	0.86	—	—
Andromeda VI	n/a	2	0.09 %	1.5	—	—
Tucana	1.5	2	0.002 %	3.9	—	—
Phoenix	4	2	39 %	0.6	85 %	−0.6

Table 1: Probabilities and T_2 values for RHB/BHB and RHB/RC to have the same radial distributions.

2 Results

Figure 1 shows the color-magnitude diagrams (CMDs) of the dSph, the selection boxes for the RHB, BHB, and if present, the RC, as well as the cumulative radial distribution of the selected populations. To quantify the significance of gradients in HB morphology, we use the Kolmogorov-Smirnoff (K-S) test, which assesses the probability that two radial distributions were drawn from the same basic population. Furthermore, we use the T_2-statistics (Da Costa et al. 1996) to compare the number ratio of $\frac{N_{\rm BHB}}{N_{\rm BHB}+N_{\rm RHB}}$, a measure of the blueness of the HB. We calculate this number ratio for the inner and outer part of the dSphs. In the case of an existing RC we compare the number ratio of RHB and RC stars. The T_2 value is equally distributed with a width of 1 around 0 for number ratios which are derived from the same distribution. A T_2 value of 1 would correspond to a $1-\sigma$ detection, while $T_2 \sim 5$ would be significant at the $5-\sigma$ level. The K-S probabilities and the T_2 values are listed in the table above. We also list the galactocentric radii covered by our data.

The two Milky Way companions Sculptor and Sextans (left) exhibit a significant radial gradient in their HB morphology in the sense that the RHB is more concentrated than the BHB (see Hurley-Keller et al. 1999 for Sculptor). In Carina no such gradient is visible for the HB, while the RC population is clearly more concentrated than the RHB. In Sculptor the RHB is much more concentrated than the BHB with a very high significance level. Of the five analyzed companions of M31 only And VI shows a significant gradient in the HB morphology. Weak gradients are visible in And I, II, and V, while And III does not show any variations. The isolated dSph Tucana has a very strong gradient. In Phoenix no significant gradient can be found, but here we are only sampling the central region (within less than half the tidal radius).

3 Conclusions

We compared the HBs of nine Local Group dSphs and of the transition type galaxy Phoenix. Where significant HB morphology variations exist the red HB populations are more concentrated than the blue ones. The existence of a morphology gradient of the HB turns out to be a common, but not a defining, feature of dSphs. While the HB alone cannot trace the full ancient star formation history (SFH), it is still a useful tool to trace the spatial history of star formation. We find no evidence that the vicinity of a massive galaxy influenced the star formation of the dSph. The HB morphology gradient in Tucana is an important result due to the fact that this galaxy is not associated with any massive spiral galaxy. If this dSph was not close to a massive galaxy while it formed stars,

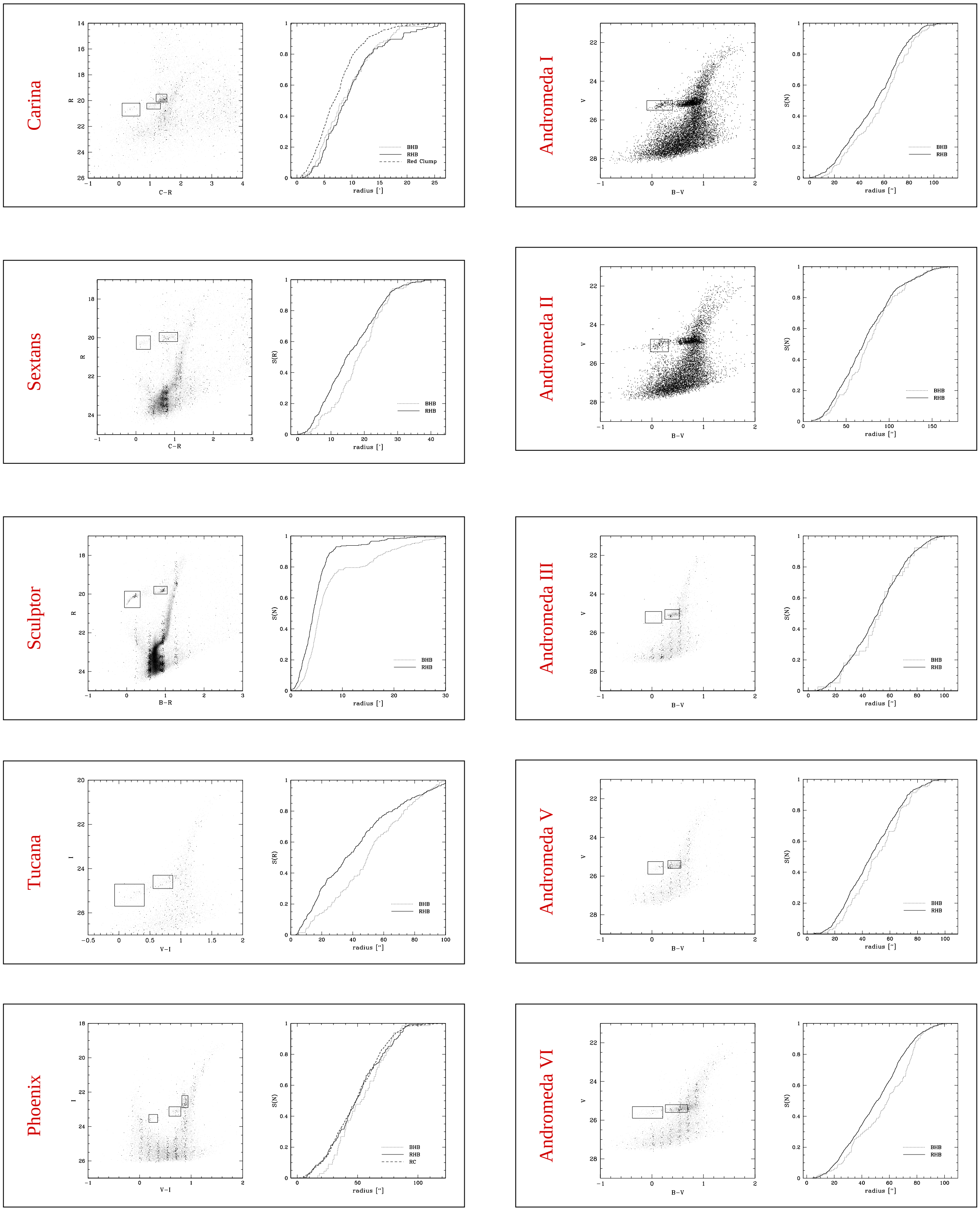

Figure 1: Color-magnitude diagrams and cumulative radial distributions for various Local Group dwarf spheroidals.

environmental effects, like tidal gas stripping, did not alter the star formation process. Moreover it looks like that the formation of population gradients in dSph is a feature caused by interior processes within a dSph or triggered by external events that are independent of a massive galaxy.

We can not distinguish whether the gradient in the HB morphology is caused by age or metallicity effects or both. Age as a single governing parameter of the HB morphology would support the idea that gas in the dSphs could be retained in the center of the dSphs for a significantly longer time than in the outskirts. Accordingly, the star formation would have taken place for a longer time only at the central regions of the dSphs. At least in the Carina dSph age is the cause as indicated by the intermediate old RC.

In contrast, if metallicity is the defining parameter for the HB morphology there is still quite a similar situation in which the self enrichment in the central region was much more efficient. In both cases the ultimate governing parameter could be the potential of the dSph which would only be capable of retaining either the star forming gas or the stellar winds with enriched material in the deepest central regions.

The presence of an HB gradient does not show a clear dependence on intrinsic parameters such as the total luminosity or on proximity to a massive spiral. What else could trigger or inhibit the formation of an HB gradient in dSphs? If the formation of a population gradient is the normal way of a dSph's evolution it may have been stopped due to collisions with intergalactic gas clouds. Such a collision may strip out the remaining gas of the evolving galaxy and stop any further star formation.

References

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