Multiple Stellar Populations in AGB stars of Galactic Globular Clusters

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Introduction

Multiple Stellar Populations (**MPs**) are a common feature of Globular Clusters (GCs). They include stars with chemical content following a specific pattern, characterized by anti-correlation of light elements, as carbon (C) and nitrogen (N), oxygen (O) and sodium (Na), magnesium (Mg) and aluminum (Al). In particular stars with abundance of light elements similar to that of old stars in the Galactic halo are named **first generation** (**1G**), while stars with enriched abundance of N, Na, and Al are called **second generation** (**2G**). A significant property of 2G stars is their **higher helium content** with respect to 1G stars.

The actual framework of MPs is based on the study of MPs at the earliest evolutionary stages, like Main Sequence (MS) and Red Giant Branch (RGB) stars. On the other side a thorough definition of their properties at later evolutionary phases is hampered by the degenerate effects of the main parameters (age and metallicity, helium and mass loss) affecting the color distribution of Horizontal Branch (HB) stars and, as a consequence, also of their progeny, namely Asymptotic Giant Branch (**AGB**) stars. As a matter of fact, studies referred to the properties of MPs in AGB stars are, to date, limited to a few cases.

The properties of MPs in AGB stars have been established through the study of the chemical content of stars. According to evolutionary prescriptions, helium-enriched stars populate the hottest end of the HB. It follows that they would skip the normal AGB phase, and evolve to the white-dwarf cooling sequence as **AGB *manqué***. Hence, a minor fraction of stars with 2G chemical composition is expected to be observed among the AGBs.

Spectroscopic analyses of GCs with extended HB morphology have shown a relative lack of 2G AGB stars. However, different works have resulted in controversial conclusions about the actual presence of 2G stars in the AGB population.

The solution to this issue, kwon as **AGB problem**, can only be obtained by an homogeneous definition of the observational properties of AGB stars in a statically significant sample of GCs. With this purpose, **we undertook and extensive analysis of the photometric properties of AGB stars in a sample of 58 Galactic GCs**, observed with the *Hubble Space telescope* in the filters F275W, F336W, F438W, F606W, and F814W of the WFC3.

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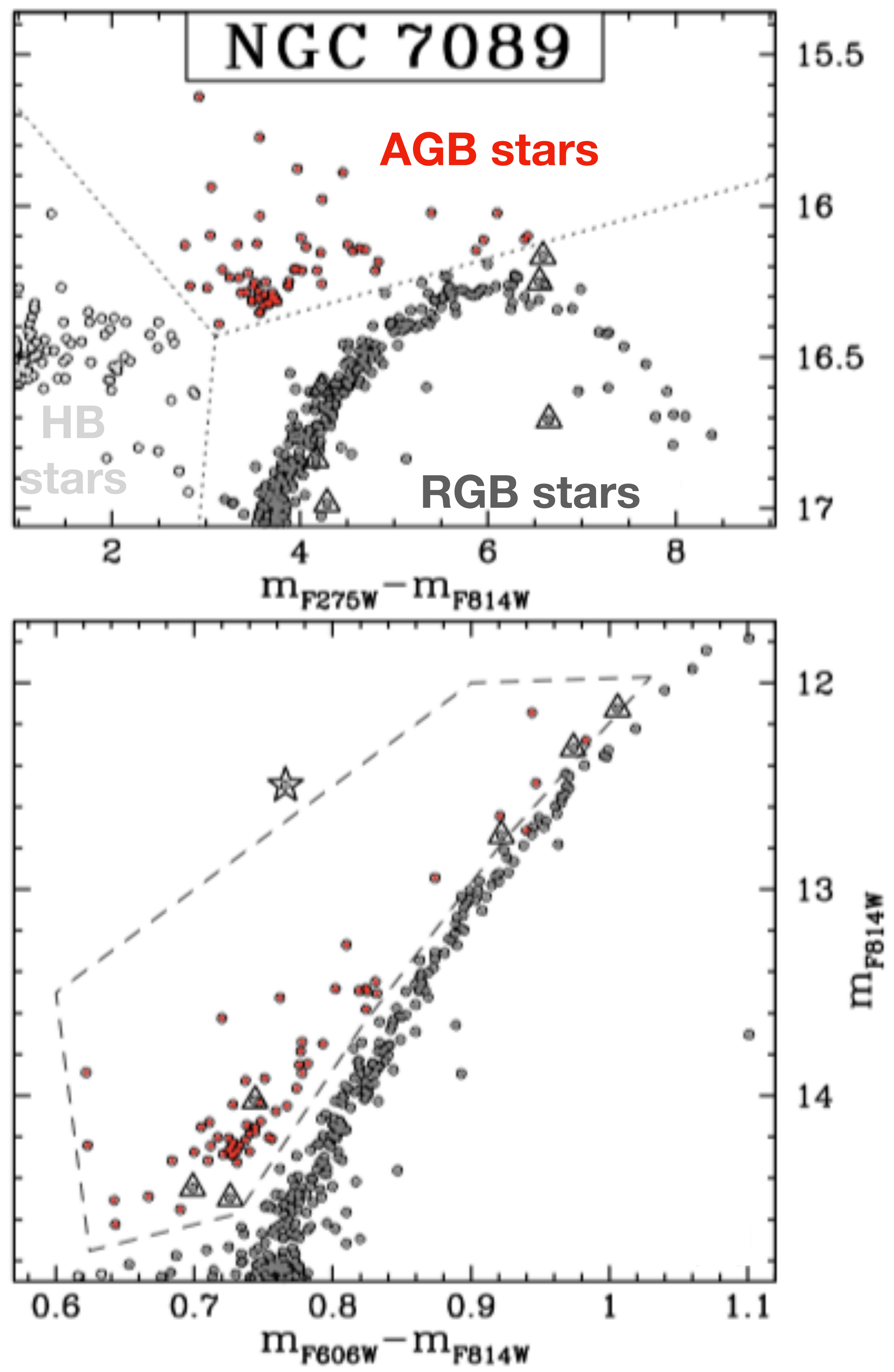
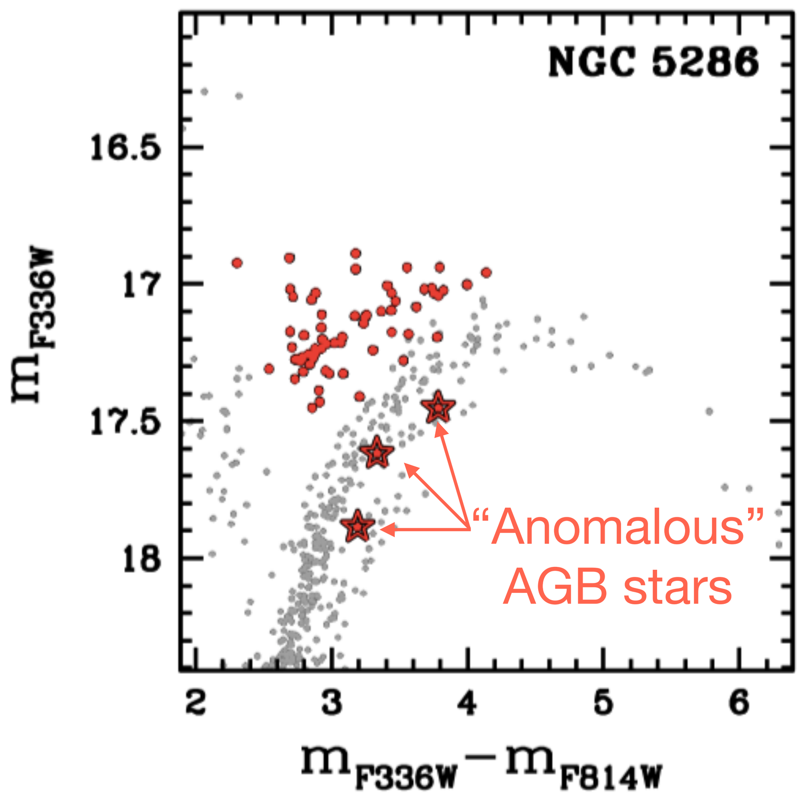
Methods

We built the color-magnitude diagrams (CMDs) of all the analyzed GCs. By exploiting the different location of AGB stars in CMDs obtained with appropriate different combinations of **UV and optical bands**, we selected the candidate AGB stars in each cluster.
An example referred to NGC 7089 is shown below.

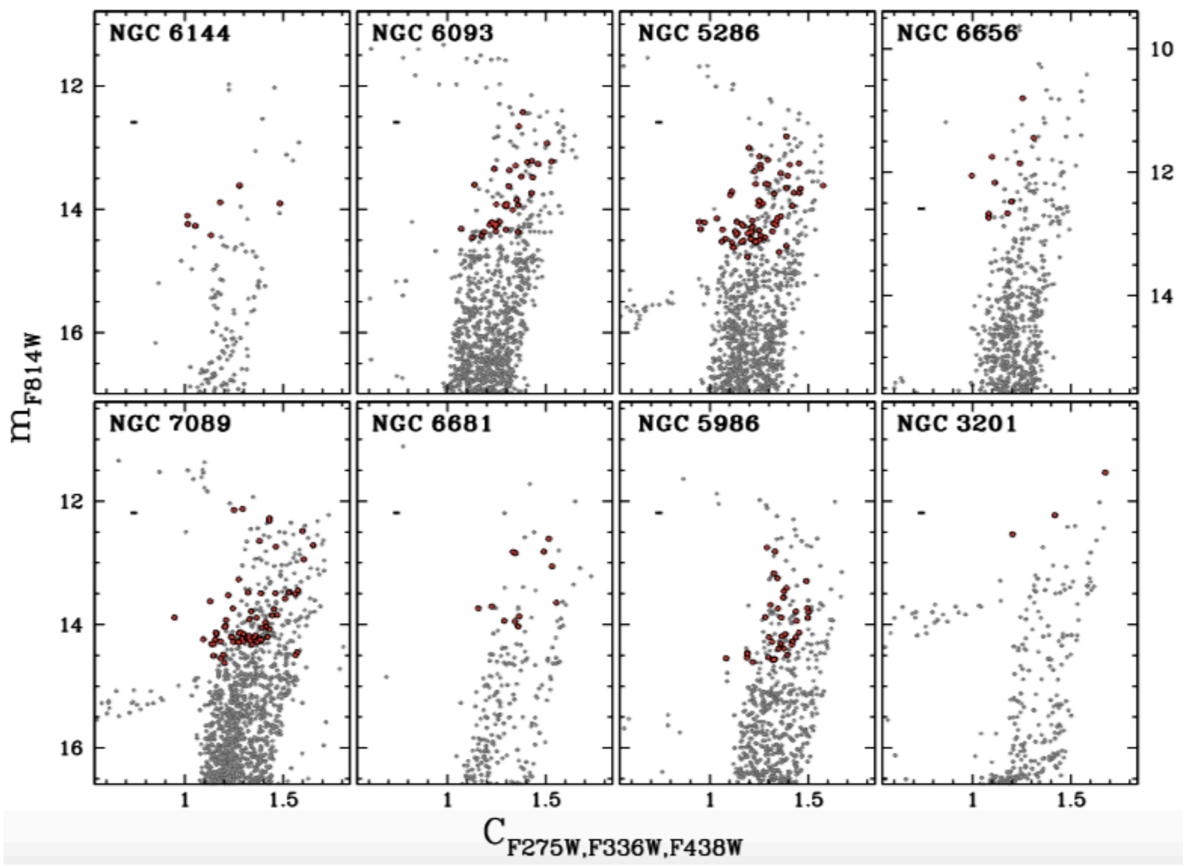


In 10 GCs included in our database, metallicity variations have been detected among their RGB stars. These stars are usually referred to as "**anomalous**". Since their AGB progeny has different properties with respect to the rest of 1G and 2G AGB stars, we also selected the candidate "anomalous" AGB population stars and studied them separately. The following CMD shows the "anomalous" AGB candidates of NGC 5286.

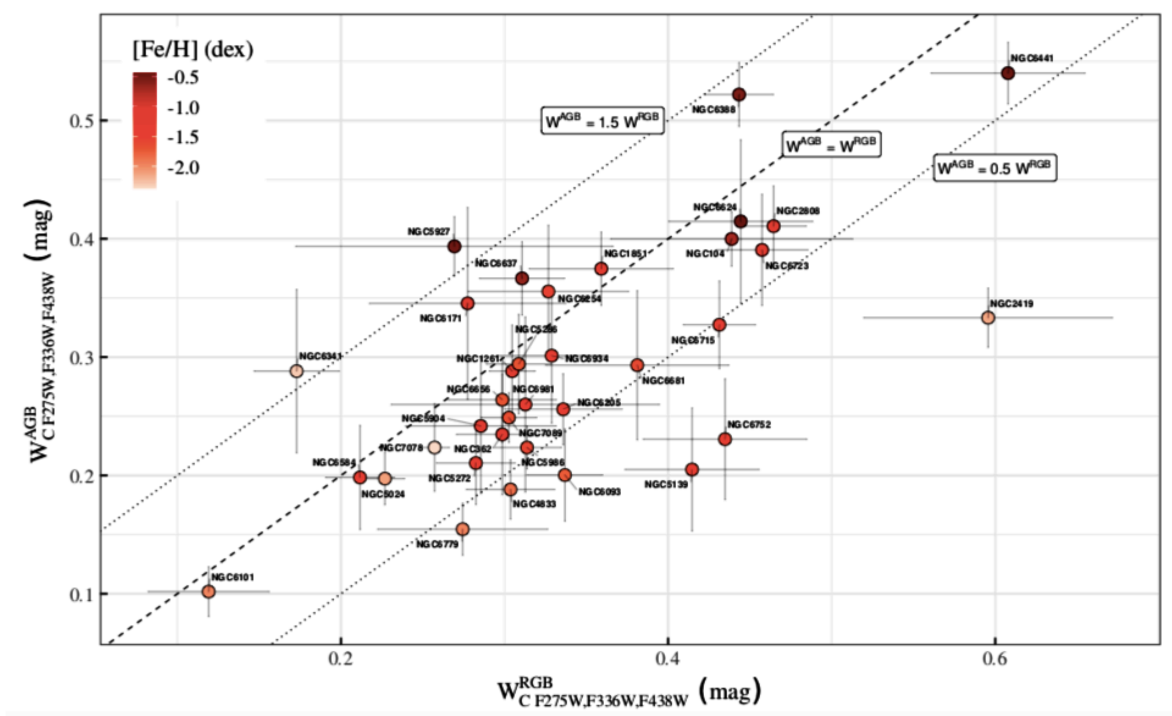


Results

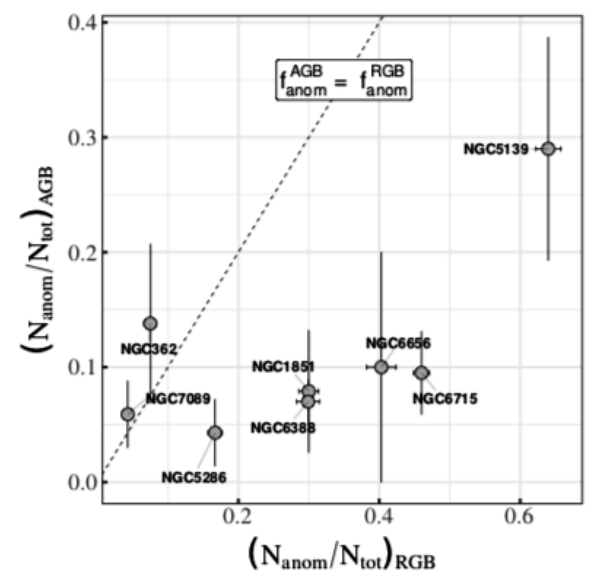
1 The spread of the AGB sequence in 48 out of 58 GCs in the indices $C_{F275W,F336W,F438W}$ = (F275W-F336W)-(F336W-F438W) and $C_{F336W,F438W,F814W}$ = (F336W-F438W)-(F438W-F814W), sensitive to variations of light-elements and helium, is larger than photometric errors. The m_{F814W} vs. $C_{F275W,F336W,F438W}$ CMDs of 8 GCs are shown below.



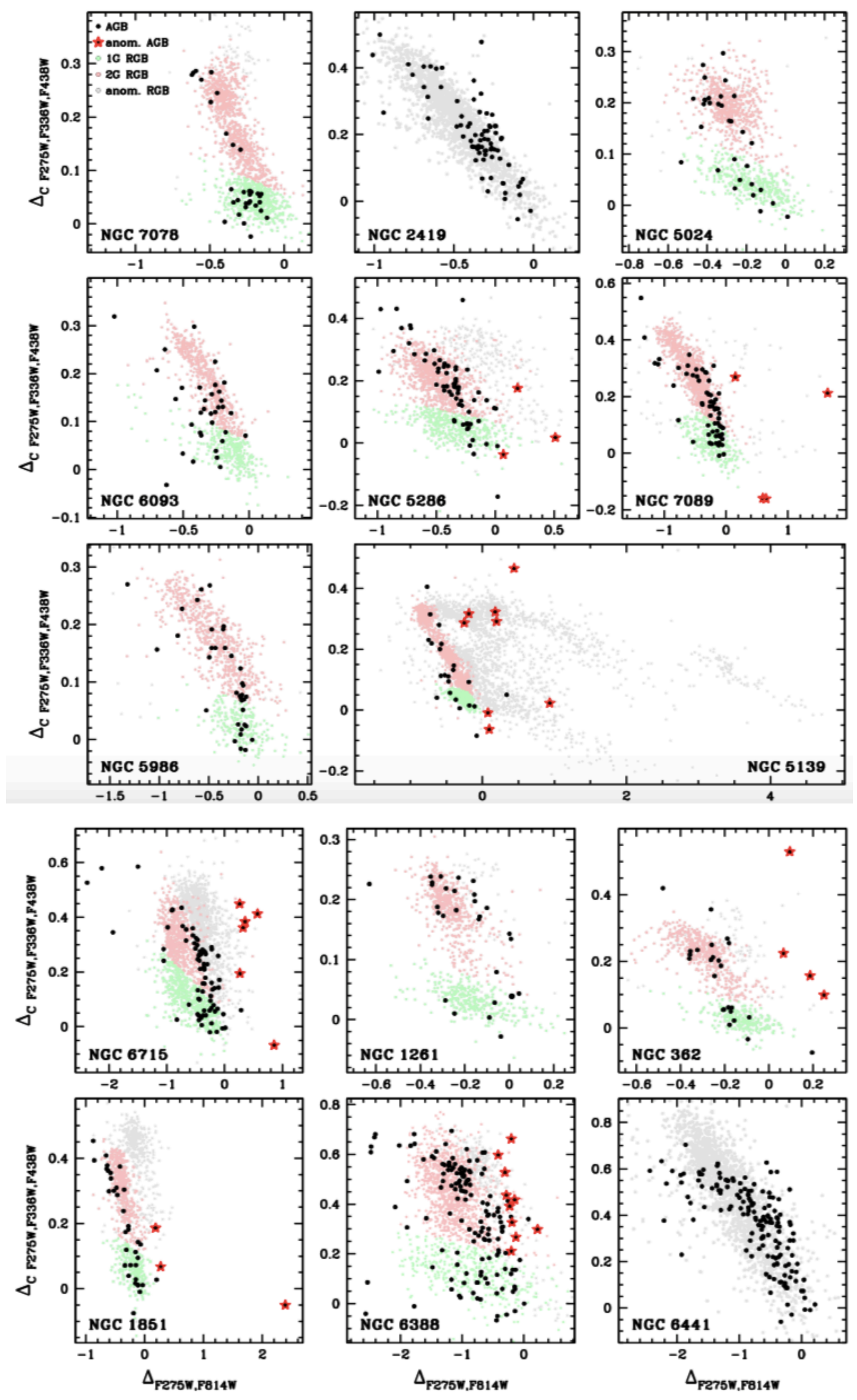
2 The intrinsic width of AGB stars, derived from the measurement of the extension of the AGB sequences in the indices $C_{F275W,F336W,F438W}$ and $C_{F336W,F438W,F814W}$, of the 35 GCs in our database with more than 10 AGB members, is on average smaller than that of the RGB stars in the same clusters. This results provides a convincing indication that part of the 2G stars in all the GCs skips the AGB phase.



3 The fraction of "anomalous" AGB stars is lower than that observed in the same clusters along the RGB. This suggests that part of the "anomalous" RGB stars does not evolve to the AGB phase.



4 For the first time the "chromosome maps" (ChM) of AGB stars in a large sample of 15 GCs have been built.



5 The fraction of 1G AGB stars derived from the ChMs allows us to compare this quantity with that derived from RGB stars. On average, 1G stars are more numerous in the AGB than in the RGB (left panel). This finding is consistent with the predictions of the AGB-*manqué* scenario by which part of helium-enriched stars is expected to avoid the standard AGB evolution. This is further confirmed by the fact that the difference between AGB and RGB 1G fraction is reconciled if we account for AGB *manqué* stars in the clusters where they can be detected (red points in the left panel). Finally a significant direct correlation exists between internal helium variation and depletion of 2G stars in AGB stars (right panel).