EXPLORING THE SIZE-AGE CONUNDRUM IN THE LMC: A STUDY OF THE GLOBULAR CLUSTER NGC 1835

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Introduction

The distribution of core radius (r_c) versus the chronological age for the globular clusters (GCs) of the Large Magellanic Cloud (LMC) is peculiar and commonly named "size-age conundrum" *(Mackey & Gilmore 2003*): all young clusters have a small core radius (r_c < 2.5 pc), while the older ones present a wide range of values. In the past, the trend was interpreted in terms of an evolutionary sequence: all clusters in the LMC were formed compact and then experienced a variable level of core expansion due to populations of binary black holes (*Mackey & Gilmore 2008*). In contrast, the variety of core radii observed in the oldest clusters has been recently attributed to their different level of dynamical evolution (*Ferraro et al. 2019*):

- systems with **larger core radius → dynamically young**
- systems with **smaller core radius → dynamically old**

Globular clusters are in fact dynamically active systems, where gravitational interactions between stars can significantly alter the energy budget of the system. As a result, processes like mass-segregation and dynamical friction can cause a progressive sinking of massive stars towards the central region, leading to a contraction of the central region ("dynamical evolution"). This work is aimed at studying **NGC 1835**, another old GC in the LMC, in order to further explore this behavior.

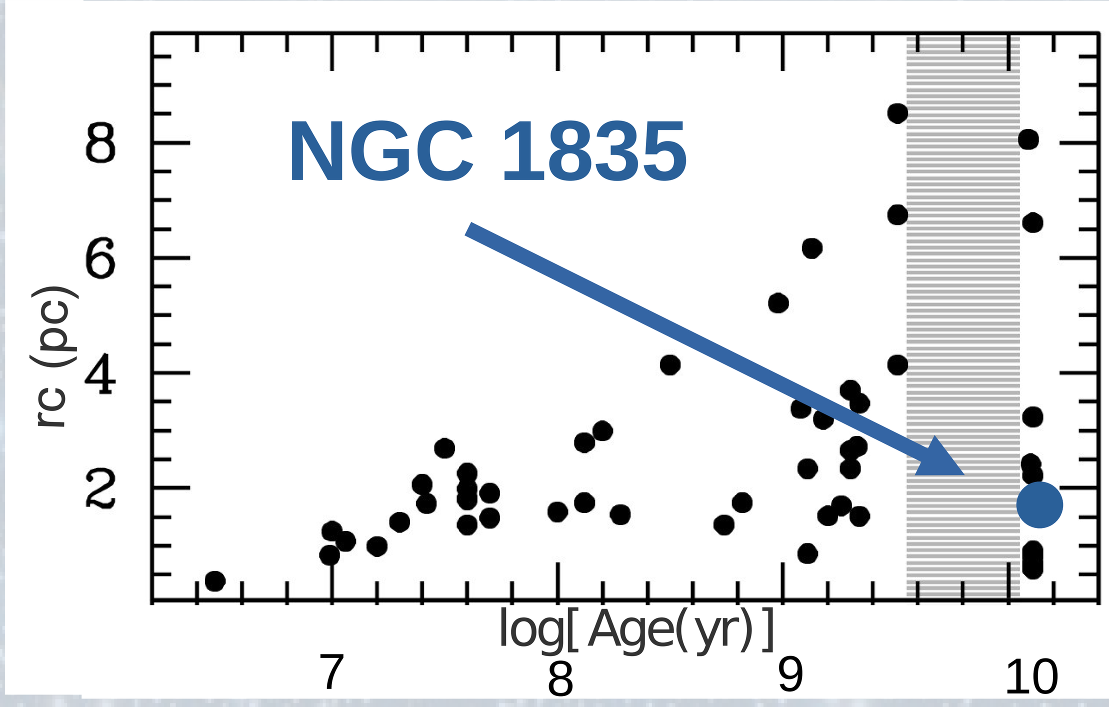


Fig.1 : Distribution of core radius versus chronological age for globular clusters in the LMC

Why NGC 1835?

In order to prove the validity of the scenario proposed in *Ferraro et al. 2019*, UV-optical HST observations were obtained for NGC 1835, which is expected to be **ONE OF THE MOST DYNAMICALLY EVOLVED** clusters in the LMC.

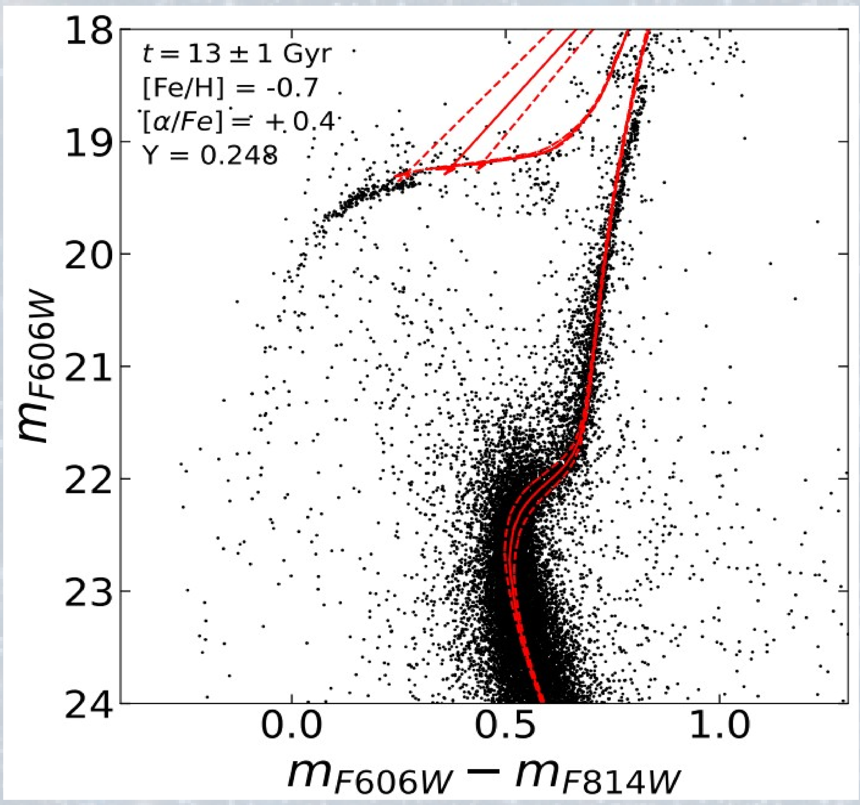
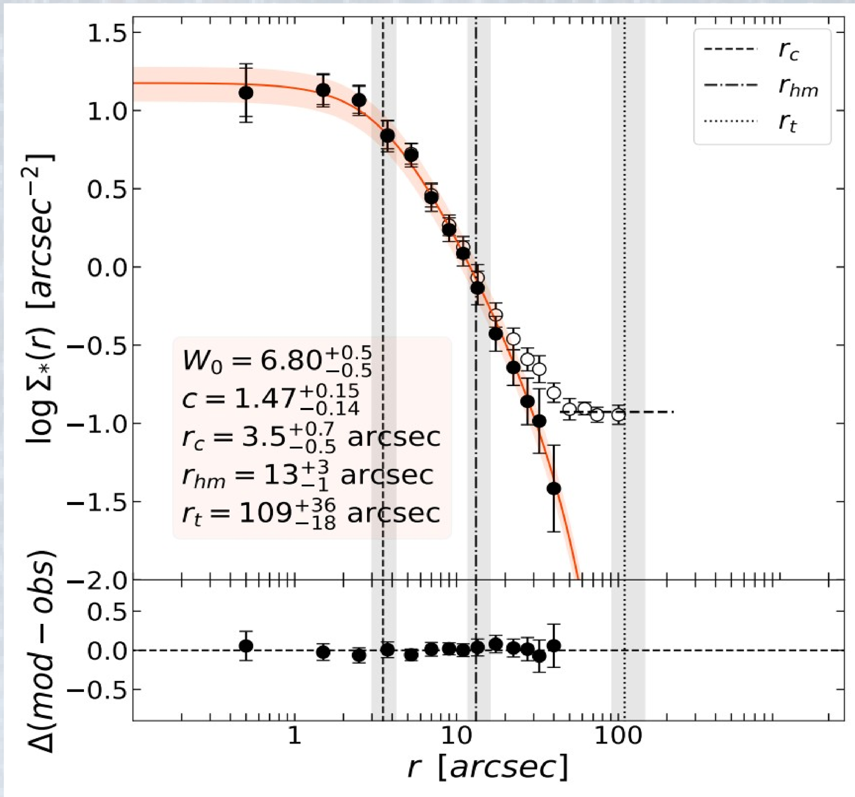


Fig.2: PARSEC isochrones superposed to the color-magnitude diagram of NGC 1835.

NGC 1835 is **AMONG THE OLDEST** globular clusters in the LMC**,** with an age of **13 ± 1 Gyr**.



NGC 1835 is very **COMPACT,** with a core radius of **3.5" (0.8 pc)** and an half-mass radius of **13" (3.14 pc).**

Fig.3 : Density profile of NGC 1835. The open circles represent the observed measures, while the filled circles are the background-decontaminated values. The red solid line shows the best-fit King model.

Dynamical age

We estimated the evolutionary stage of the cluster by measuring the **level of radial segregation of its Blue Straggler Stars (BSSs)** through the A+ parameter. This is defined as the area between the cumulative radial distribution of BSSs and that of a lighter reference population (e.g., red giant stars).

A+ has been found to strongly correlate with the dynamical age of star clusters (see Fig.6; *Lanzoni et al. 2016, Ferraro et al. 2018, 2023*)

→ In NGC 1835 we found **A^+=0.28 ± 0.04,** which is the largest value ever obtained for the LMC clusters.

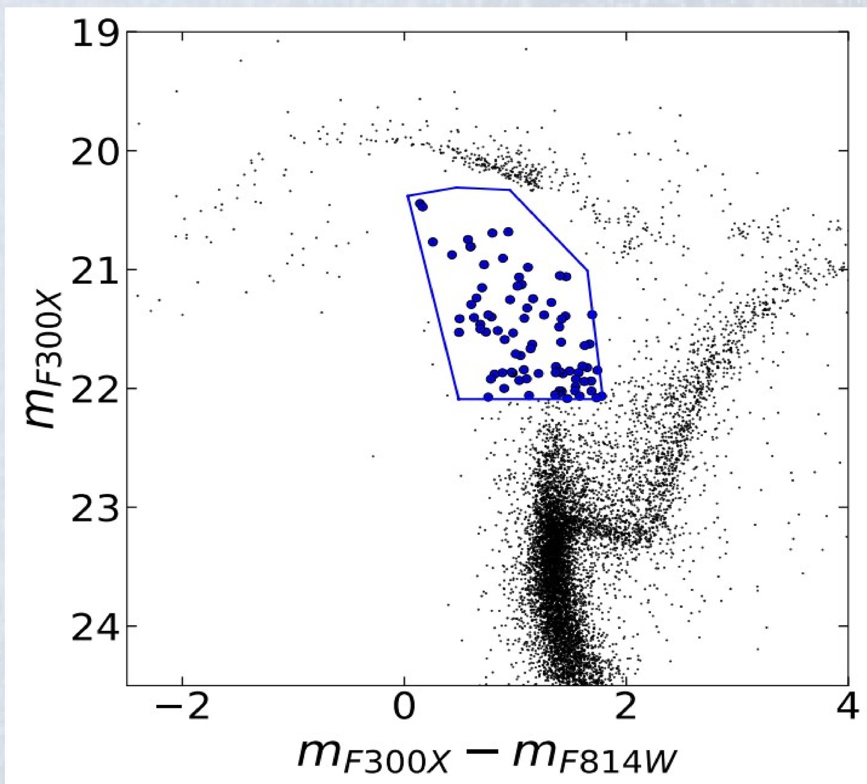


Fig.4: Selection of the BSS sample

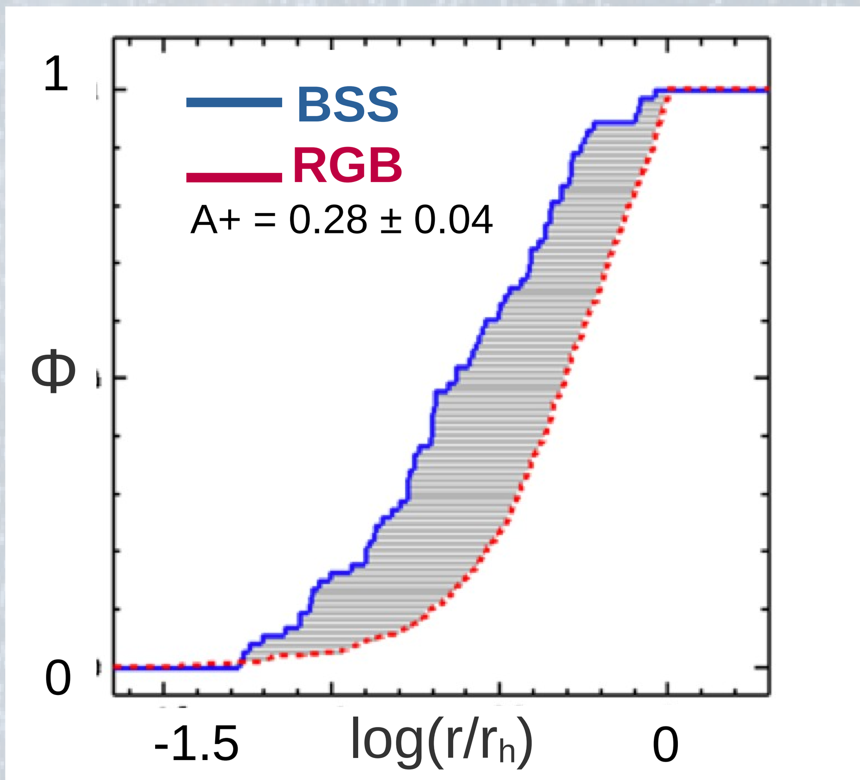


Fig.5 Cumulative radial distribution of BSSs and red giant branch (RGB) stars. The area of the shaded region is the value of A+

Conclusions

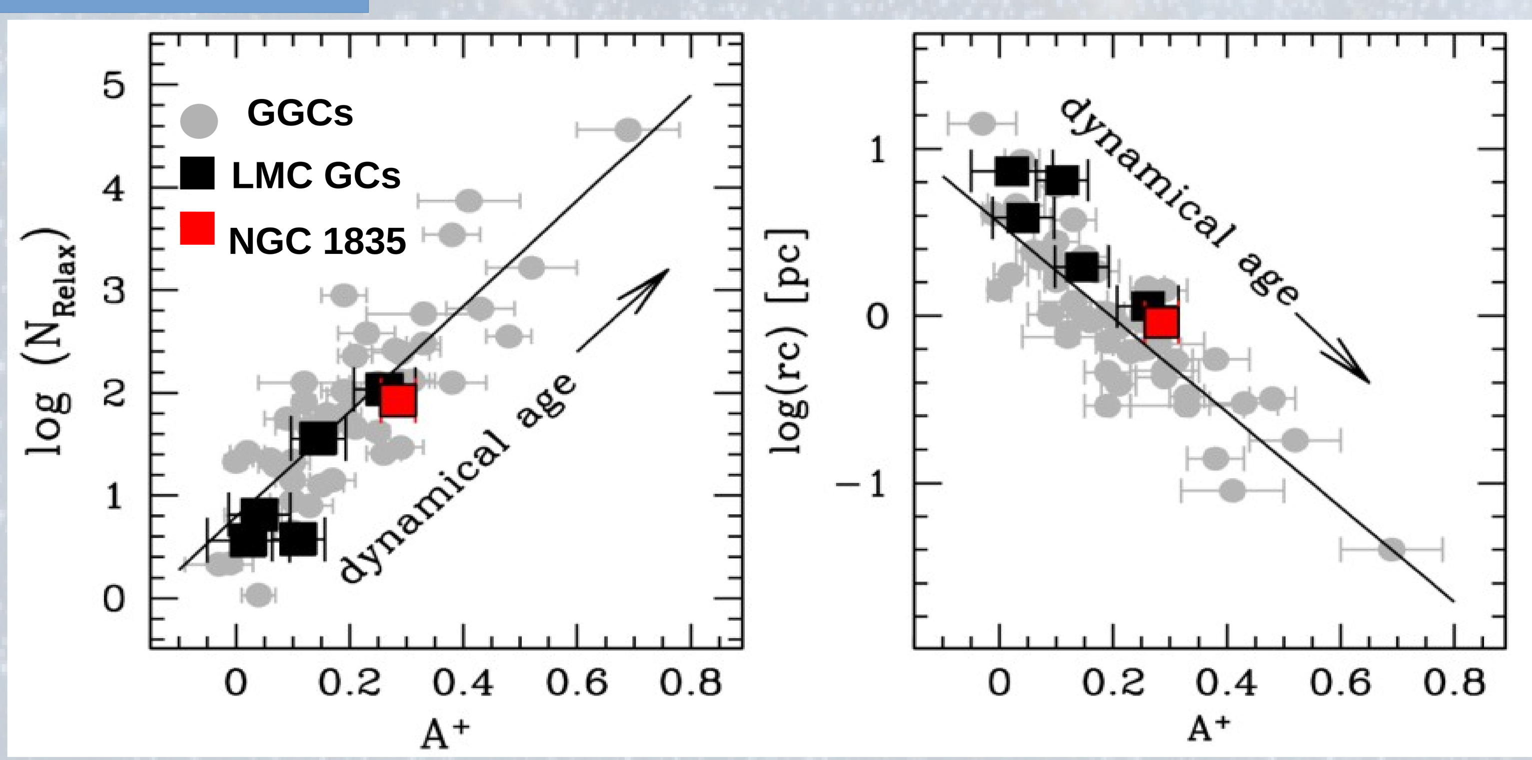


Fig.6. Left panel: relation between the A+ and the number of current central relaxation times for Galactic (grey circles) and LMC (black squares) clusters, and for NGC 1835 (red square). Right panel: relation between A+ and the core radius for the same systems.

-NGC 1835: <u>is the most dynamically-evolved cluster studied so far in the LMC</u>. It perfectly fits within the anticorrelation between core radius and A+ already known (see Fig.6) for five LMC clusters and 48 Galactic globular clusters (GGCs).

-Dynamical age differences among old LMC clusters: the results confirms that <u>the value of the core radius in the oldest LMC clusters is set by internal dynamical evolution (with no need of invoking the action of binary black holes).</u>

-What about the young LMC clusters? Only low-mass systems (M<10^5 Msun) have formed in the last ~3 Gyr in the LMC (central panel of Fig.7) , and they are all located in the innermost galactic regions (bottom panel of Fig.7). The lack of young clusters with a large core radius could be due to the fact that only the most compact systems were able to survive the LMC tidal forces. This also indicates that the historical "evolutionary sequence" hypothesis cannot hold, since the young cluster population does not resemble that of the progenitors of the currently old clusters, which are much more massive (by up to factors of 100) and orbit at any distances from the centre.

But why only relatively low-mass clusters formed in the last 3 Gyr in the LMC?

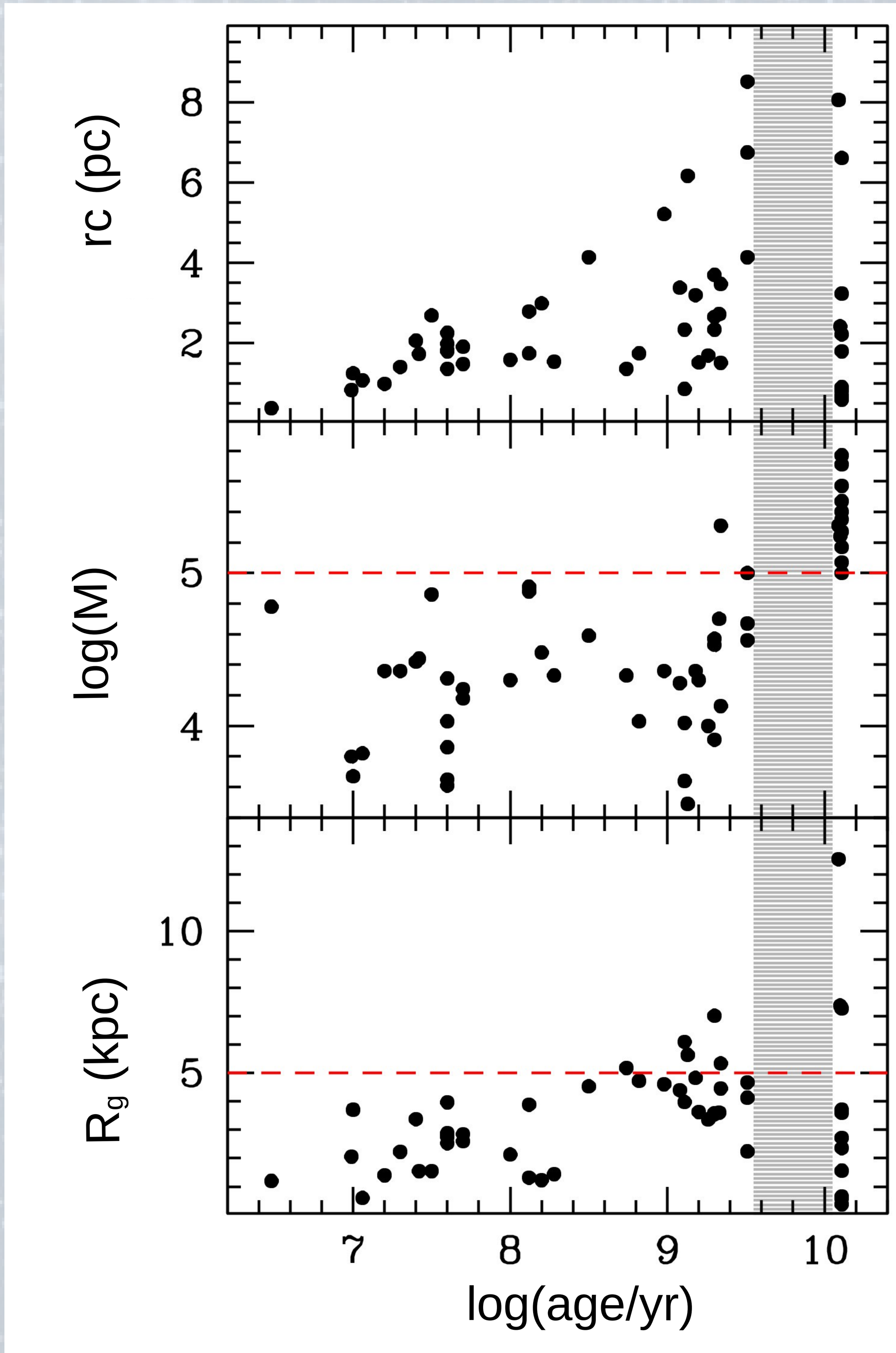


Fig.7. Observed distribution of rc (a), total mass (M) (b) and galactocentric distance (Rg) (c) versus chronological age for the LMC GCs.

References: Mackey & Gilmore, 2003, MNRAS, 338,85; Mackey & Gilmore, 2008, MNRAS, 386, 65; Ferraro et al. 2019, Nat. Astr, 3, 1149; Lanzoni et al. 2016, ApJL, 883, L29; Ferraro et al. 2018, ApJ, 860, 365; Ferraro et al., 2023, ApJ, 950, 145;

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