



# **Structural parameters, chronological age and dynamical age of the LMC globular cluster NGC 1754**

arXiv:2505.10323v1

Reporter: Jiayu QI

2025.05.23

# 1. Introduction

- **Large Magellanic Cloud (LMC):** hosts many globular clusters (GCs); provides information about processes of star cluster formation and evolution.
- **Size-age conundrum:** the youngest clusters ( $t < 3$  Gyr) have compact radii ( $r_c < 2.5\text{pc}$ ), older ones span a range from 2.5 to 10 pc.
  - **Alternative explanation:** observed spread in core radius of the oldest cluster is result of internal dynamical aging(Ferraro et al. 2019).
  - **Mass segregation:** the most massive stars tend to transfer kinetic energy to lower-mass objects and sink towards the system's center.

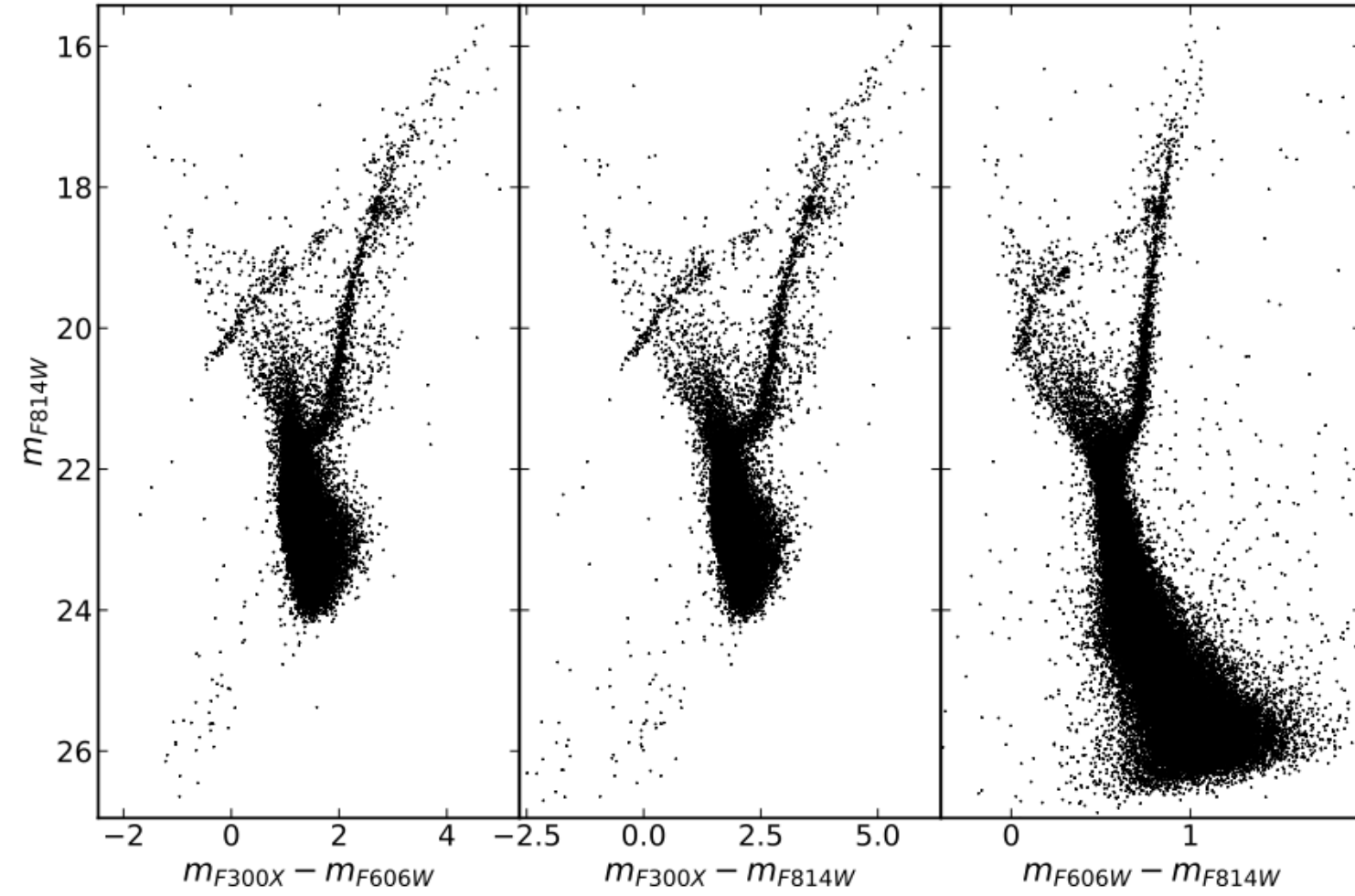
# 1. Introduction

- **Star clusters with the same chronological age can be different stages of internal dynamical evolution.**
- **“Dynamical clock”**: an empirical method based on the degree of central segregation of blue straggler stars (BSSs).
  - $A_{rh}^+$ : defined as the area enclosed between the cumulative radial distribution of BSSs and that of a reference population within one half-mass radius ( $r_h$ ) from cluster center.
- **Globular cluster NGC 1754**
  - A new set of optical and UV high-resolution HST images
  - A very old chronological age:  $t \sim 15$  Gyr (Mackey & Gilmore 2003)
  - A very compact core radius:  $r_c = 0.88$  pc (Mackey & Gilmore 2003)
  - $[\text{Fe}/\text{H}] \sim -1.45$  (Mucciarelli et al. 2021)

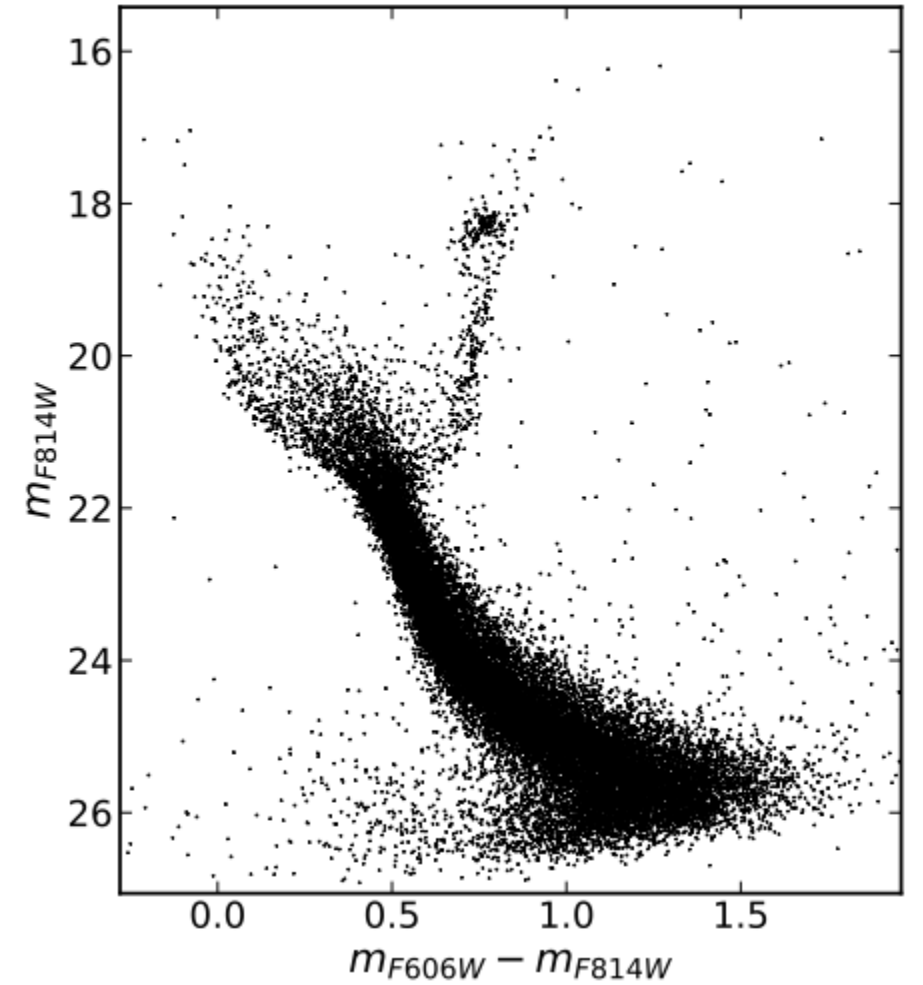
## 2. Data analysis

- 16 high-resolution images taken by HST's WFC3(in the near-UV F300X, F606W, and F814W).
- 13 images taken by HST's ACS in F606W and F814W, sampling a field region.
- **Data reduction: DAOPHOT II (Stetson 1987).**
- Apply the standard calibration process, converting the magnitudes to the VEGAMAG reference system.
- Obtained absolute coordinate system( $\alpha, \delta$ ): using the coefficients for WFC3 and ACS, the catalogs were astrometrized by cross-correlation with a Gaia DR3 of the same area.

## 2. Data analysis



**Fig. 1** CMD of NGC 1754 obtained from the data reduction of the WFC3 dataset in all the filter combinations.

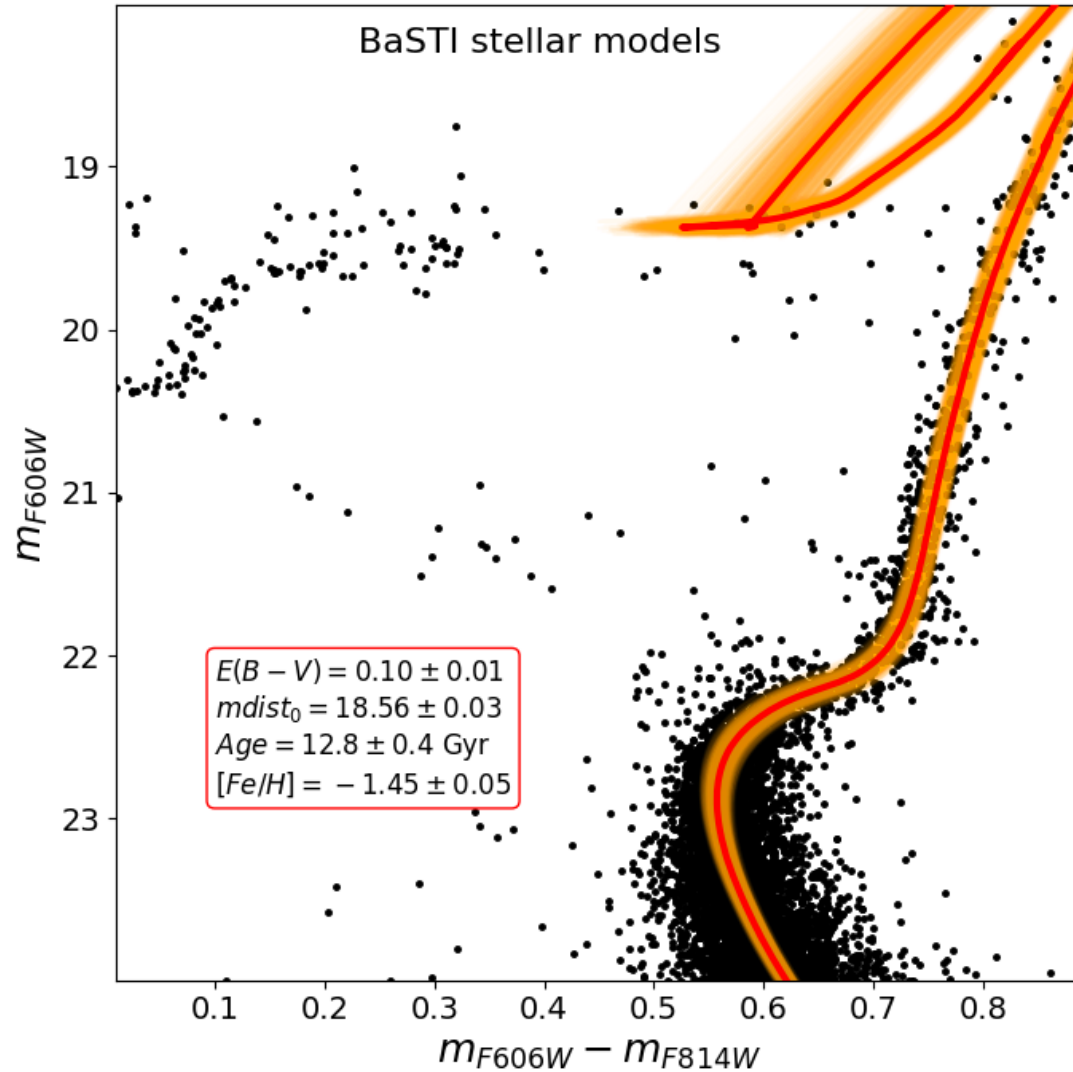


**Fig. 2** CMD of the field region obtained from the data reduction of the ACS dataset.

### 3.1 Chronological age, reddening and distance modulus

- Determined the chronological age: an isochrone fitting that compares the observed CMD of the cluster with a set of isochrones by using **Bayesian method**.
- **BASTI isochrones:** downloaded with standard helium abundance ( $Y = 0.25$ ) and  $[\alpha/Fe] = +0.4$ , for ages from 9.0 to 14.0 Gyr, and  $[Fe/H]$  from -1.8 to -0.95.
- Key comparison: between the CMD and the isochrones around the MSTO, SGB and lower portion of the RGB.
- Gaussian prior distribution: 1)  $[Fe/H] = -1.45 \pm 0.05$  (Mucciarelli et al. 2021); 2) color excess  $E(B-V) = 0.13 \pm 0.02$  and distance modulus  $(m - M)_0 = 18.58 \pm 0.05$ .

### 3.1 Chronological age, reddening and distance modulus

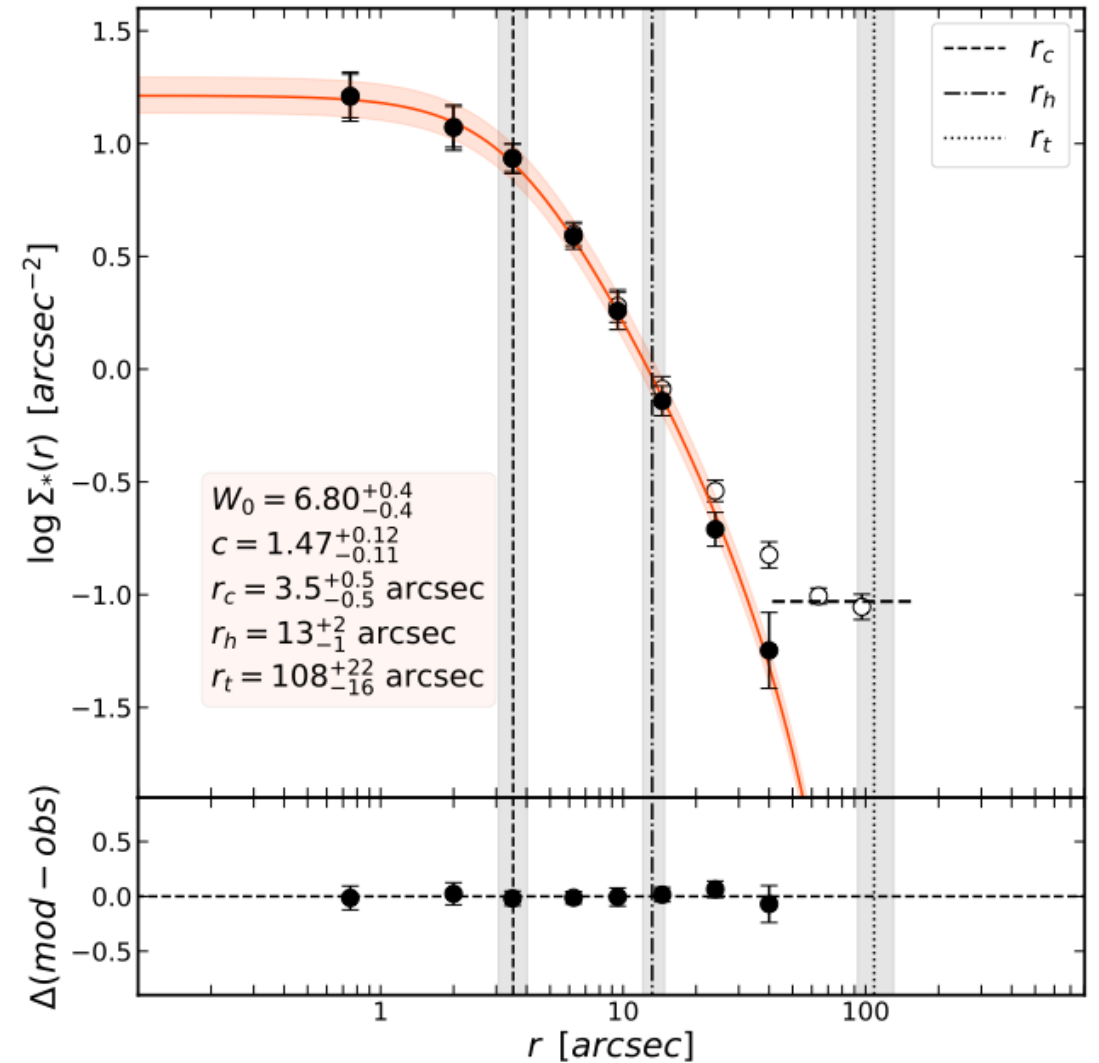


- Uncertainties of best-fit values are determined by calculating the 16<sup>th</sup> and 84<sup>th</sup> percentiles of each parameter's probability distribution in MCMC procedure.

**Fig. 3** Best-fit BASTI isochrone of NGC 1754 by red solid line. The orange-shaded envelope represents the  $1\sigma$  uncertainty region of the best-fit isochrone.

## 3.2 Density profile and structural parameters

- Averaged the **plateau points** to obtain the value of the field star density, and then subtracted this value from each bin to obtain the field-decontaminated cluster profile.
- King model fit (King 1966).



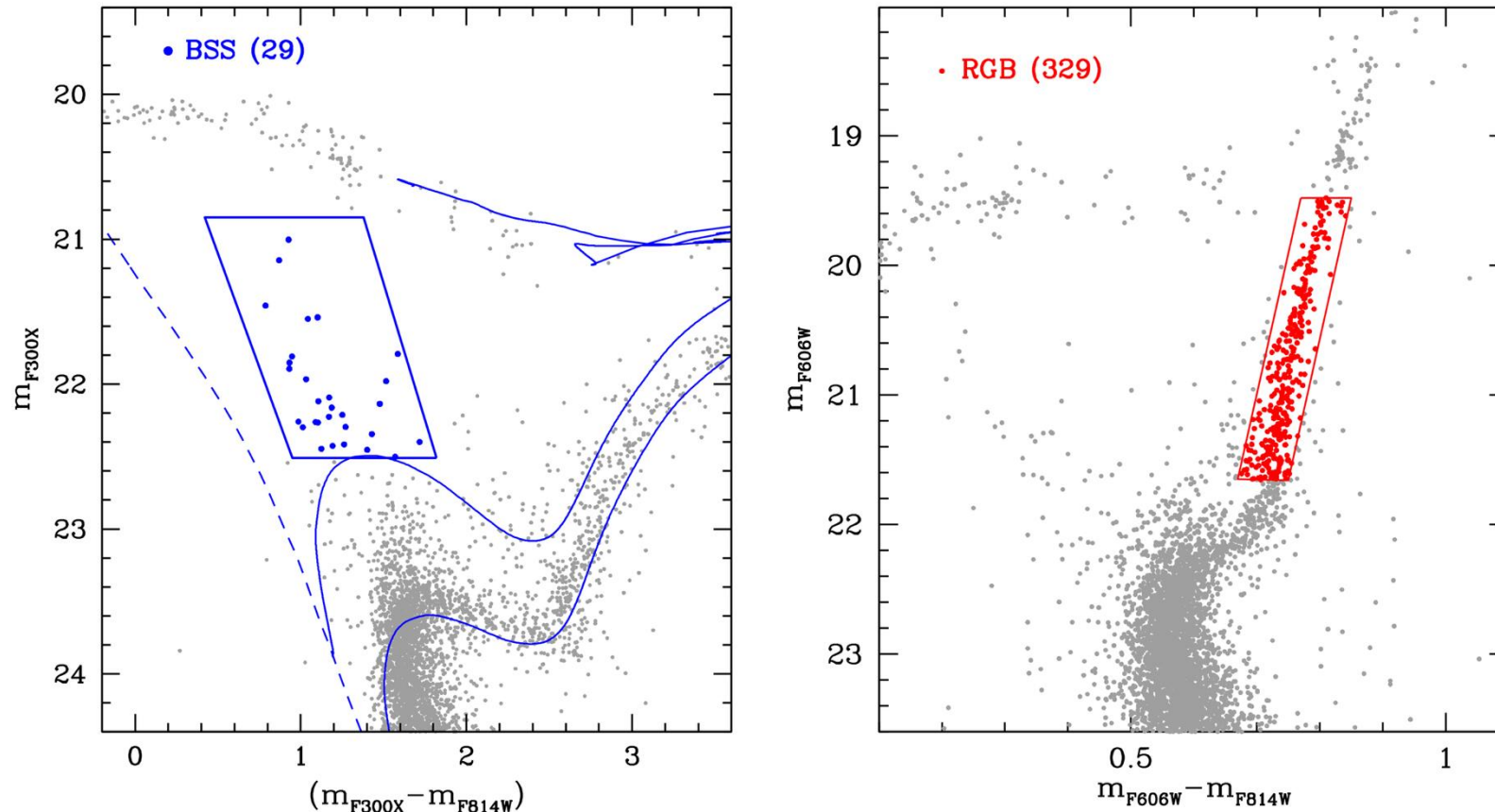
**Fig. 4** The projected density profile of NGC 1754. The horizontal dashed line represents the mean LMC field density.



### 3.3 Measuring the dynamical age

- “**dynamical clock**”: evaluate the system’s dynamical state by analyzing the degree of central segregation of BSSs compared to a lighter-mass reference population.

➤ **Select sample**

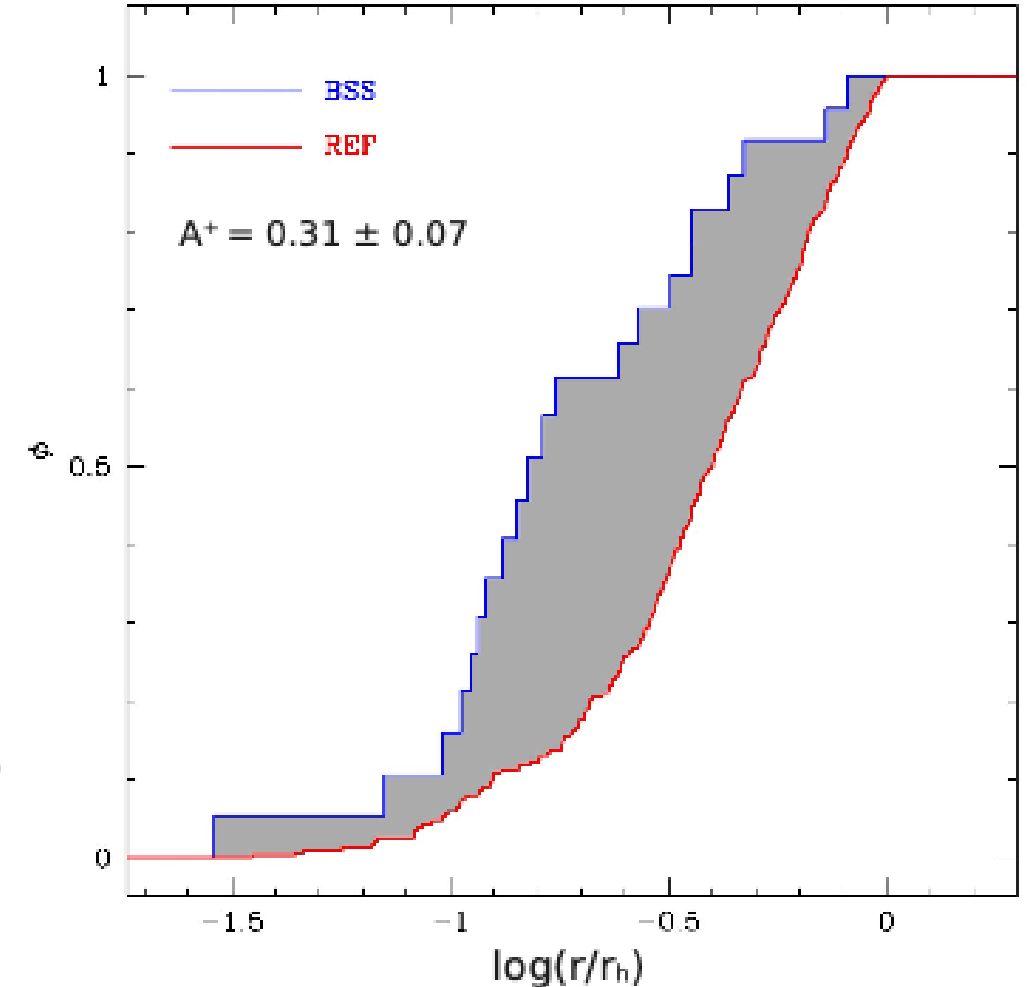


**Fig. 5** Selections of the BSS and RGB samples.

### 3.3 Measuring the dynamical age

- Measure  $A_{rh}^+$ : Cumulative radial distribution of both BSS and RGB samples.
- The value of  $A_{rh}^+$ : the area enclosed between the cumulative radial distribution of the BSS and that of RGB sample.

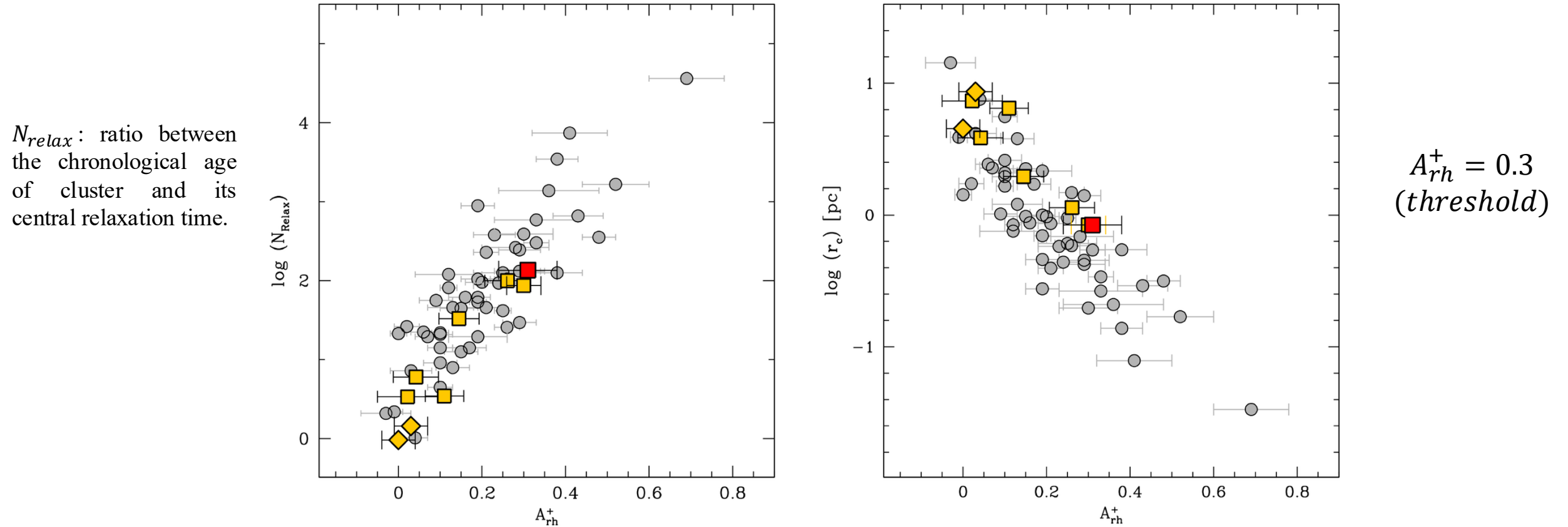
$$A^+(x) = \int_{x_{min}}^x \phi_{BSS}(x') - \phi_{REF}(x') dx' \quad (Lanzoni et al. 2016)$$



**Fig. 6** The normalized cumulative radial distributions of BSSs (blue line) and RGB stars (red line).

## 4. Discussion

- The chronological age of NGC 1754 ( $t = 12.8 \pm 0.4$  Gyr): consolidates the beginning of the GC formation process is contemporaneous in the MW and the LMC.
- The value of  $A_{rh}^+$  ( $0.31 \pm 0.07$ ): an advanced dynamical stage; seems to flag the core collapse.



**Fig. 7** Left panel: the relation between  $N_{relax}$  and  $A_{rh}^+$ ; right panel: between  $r_c$  and  $A_{rh}^+$  for star clusters analyzed using the dynamical clock method.

## 5. Conclusions

- NGC 1754 is very compact GC ( $r_c = 0.84 \text{ pc}$ ).
- NGC 1754 has a very old age ( $t = 12.8 \pm 0.4 \text{ Gyr}$ ): consolidates the process of GC formation started at the same cosmic time in the LMC and MW.
- The value of  $A_{rh}^+$  for NGC 1754 ( $A_{rh}^+ = 0.31 \pm 0.07$ ): the highest measured so far for LMC cluster; has an advanced dynamical age; possibly on the verge of core collapse.
- Natural dynamical evolution of globular clusters plays a role in shaping the age-core radius distributions observed in the LMC.

*Thanks !*