Discovery of a Double Sequence of Blue Straggler Stars in the Core-collapsed Globular Cluster NGC 6256

https://doi.org/10.3847/1538-4357/aca016

Reporter: Jiayu Qi

Supervisor: Edoardo Lagioia

Date: 2025.11.14

Introduction

- **Blue Straggler Stars (BSSs)**
  - Located: **more luminous and bluer** region than MSTO in CMD.
  - **Two main formation mechanisms:** 1) mass transfer and/or coalescence in binary systems (MT-BSSs); 2) direct collisions (COL-BSSs).
  - **More massive:** used as particles to study cluster internal dynamics.
- The difference between MT-BSSs and MT-BSSs: collision rate of the cluster, the fraction of binaries and their impact on internal dynamics, and insights into the formation and evolution of BSSs.

Introduction

- **Post-Core-Collapse (PCC) clusters** (M30, NGC 362, NGC 1261, M15 and NGC 2173)
  - Presence of two distinct BSS sequence in the CMD.
  - A **narrow sequence of blue BSSs**, separated through **a clear-cut gap** from a more scattered red BSS population in the CMD.
- **GC NGC 6256:**
  - Age = 13 $\pm$ 0.5 Gyr
  - Dense cluster (log $\rho_0 \approx 5.9$ in units of $M_\odot\, pc^{-3}$; Baumgradt & Hilker 2018)
  - Located in the Galactic bulge, 6.8 kpc from the Sun (Cadelano et al. 2020)
  - Low metal content ([Fe/H] = -1.6; Vasquez et al. 2018)
  - **PCC cluster:** presence of a central surface brightness cusp (Cohen et al. 2021)

Data Analysis

- ***High-resolution data set (HST)*** .
  - UVIS channel of the WFC3 (F555W and F814W) and WFC of the ACS (F606W and F814W).
  - Data reduction: DAOPHOT and ALLFRAME packages.
  - Temporal baseline (~10yr): measure PMs.
- ***Wide-filed data set (VVVX survey).***
  - VISTA InfraRed CAMera (VIRCAM) mounted on the VISTA-ESO telescope (J, H and Ks filters).
  - Data reduction: DAOPHOT and ALLFRAME packages.
- The final catalog was astrometrized and instrumental magnitudes were calibrated.

Stellar Density profile and Structural Parameters

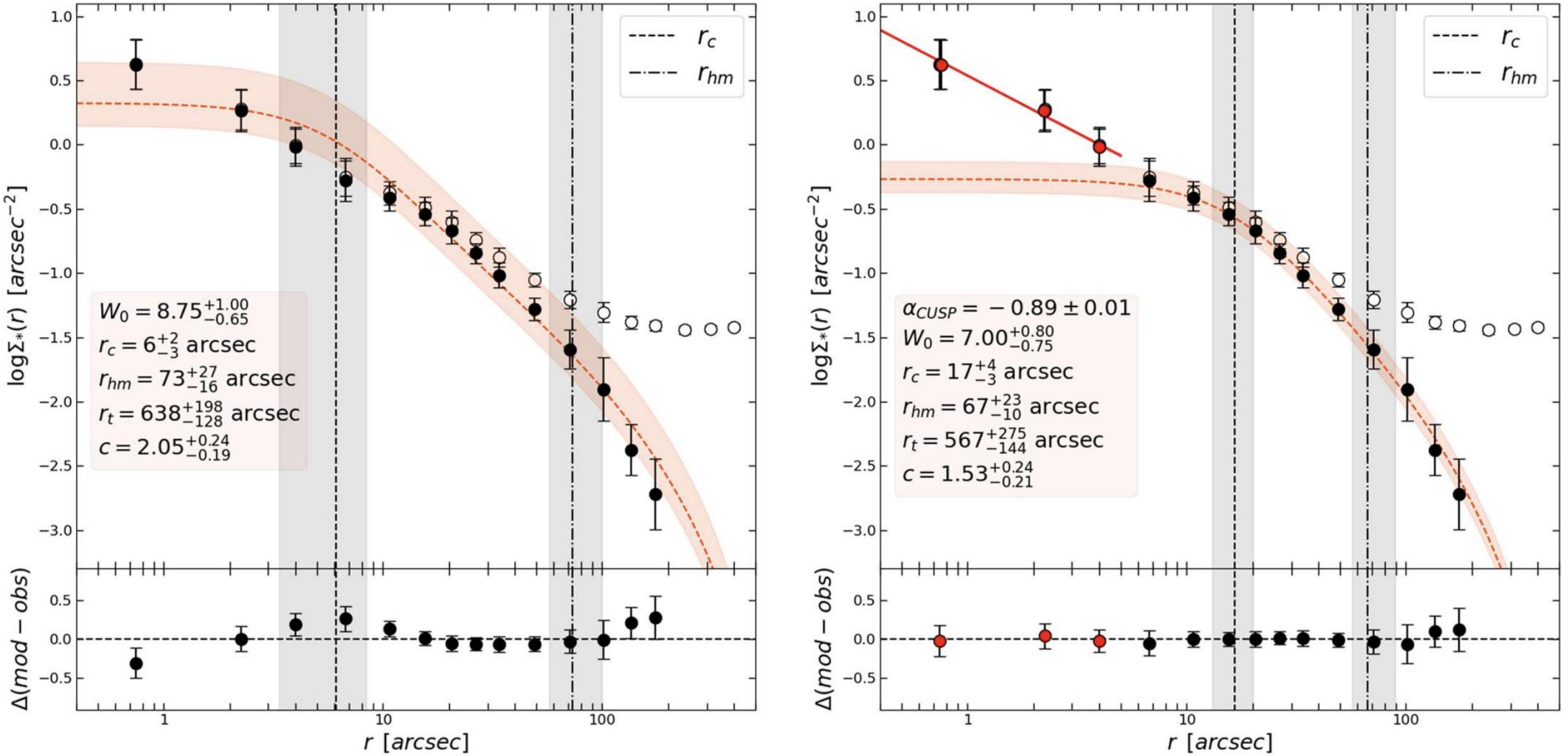

Fig.1 observed (empty circles) and background-subtracted (filled circles) density profile of NGC 6256.

Proper Motion Selection

- ***Relative Proper Motion (PM) measurement.***
  - Two epochs (~10 yr): 1) WFC3; 2) ACS (reference frame, larger FOV).
  - **Transformation:** 1) Use likely cluster members to derive 6-parameter linear transformations; 2) Transform WFC3 positions to ACS reference frame.
  - Relative PM $= (POS_{Epoch2} - POS_{Epoch1})/baseline \times pixel\_scale$
- ***Member selection.***
  - **PM Distribution:** Fitted with Gaussian functions ($\sigma \sim$ 0.21mas/yr in both RA/Dec).
  - **Selection Threshold:** Retained stars within **combined dispersion** ~ $2\sqrt{\sigma_x^2 + \sigma_y^2}$ (Total PM < 0.6 mas/yr).

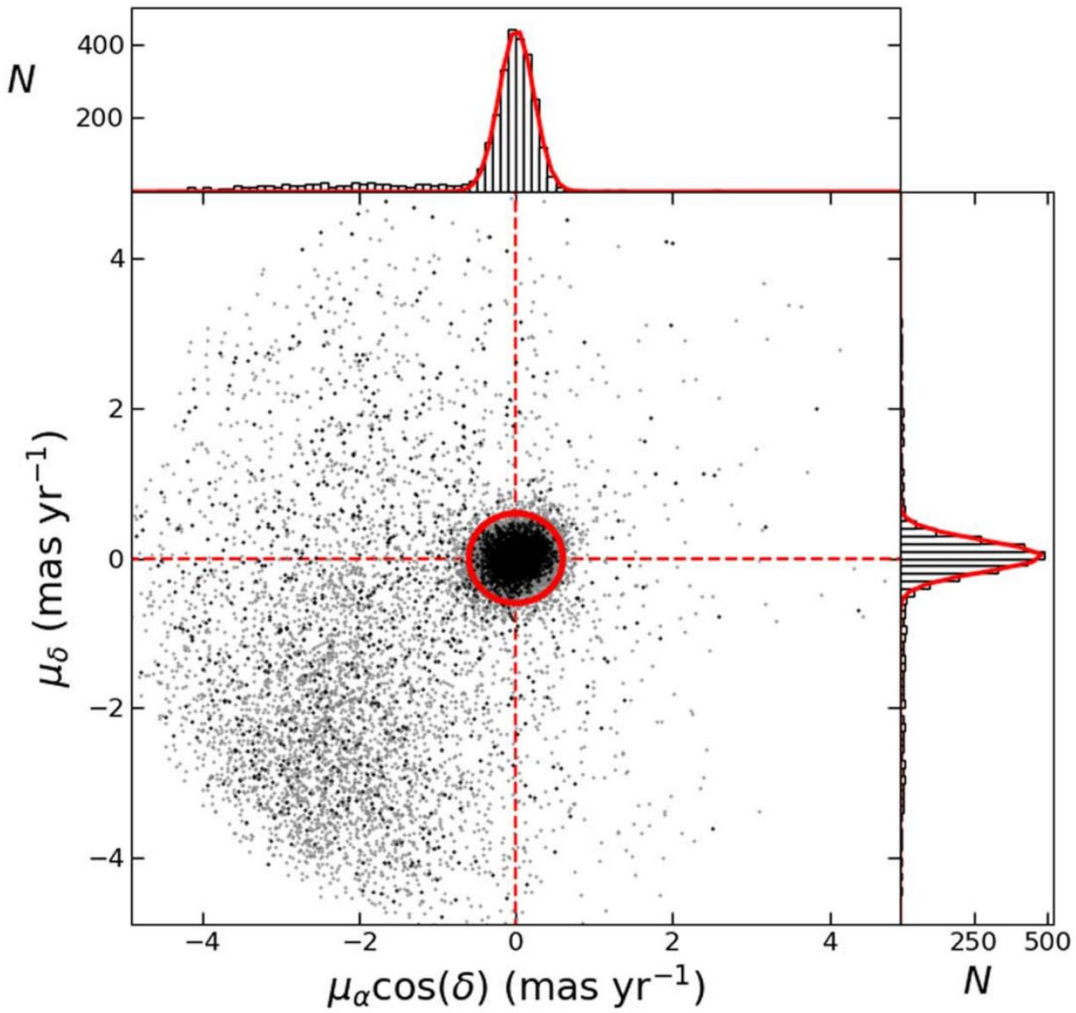

Fig.2 vector point diagram of the stars between the two HST epochs.

Proper Motion Selection

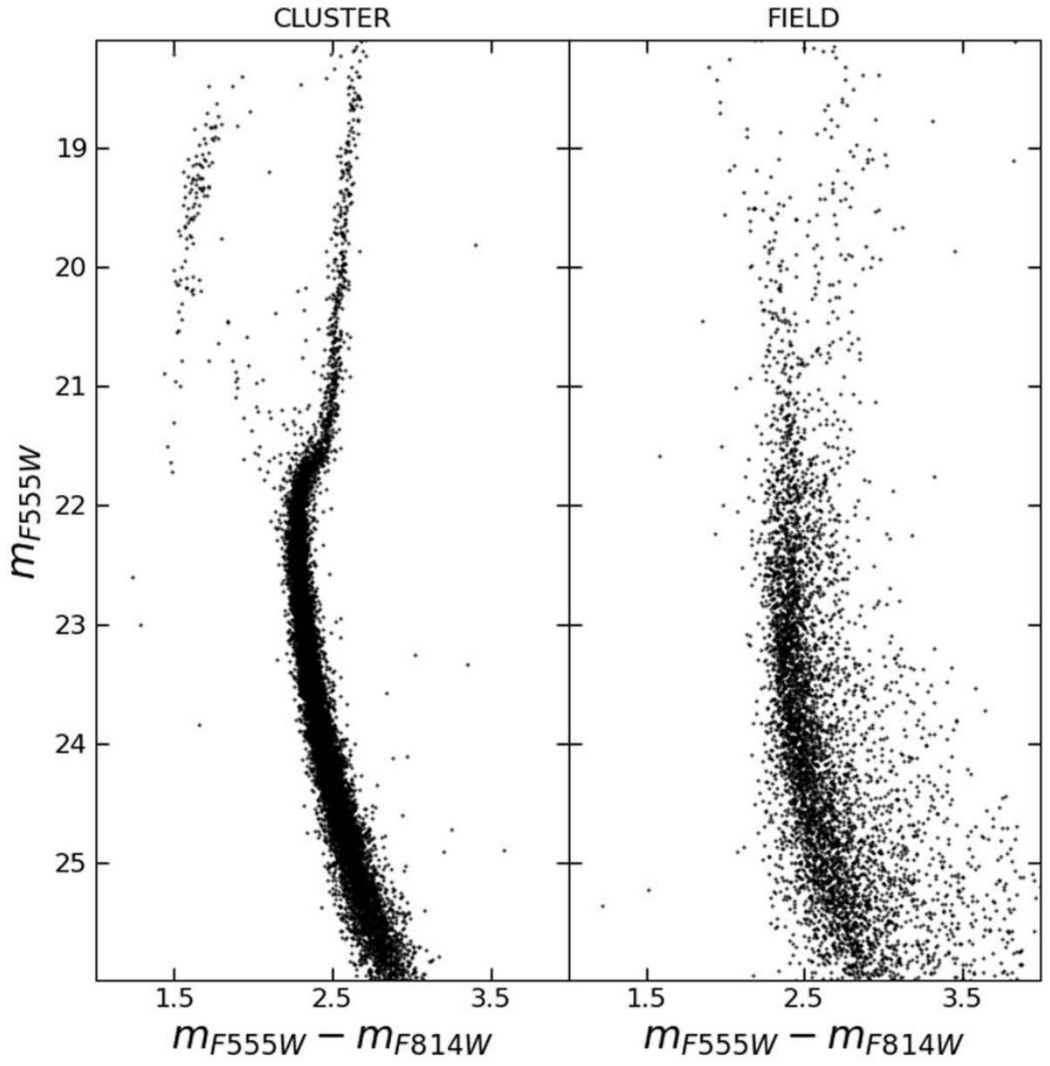

Fig.3 CMDs of the WFC3 data for all stars selected as members and for the stars selected as field interlopes.

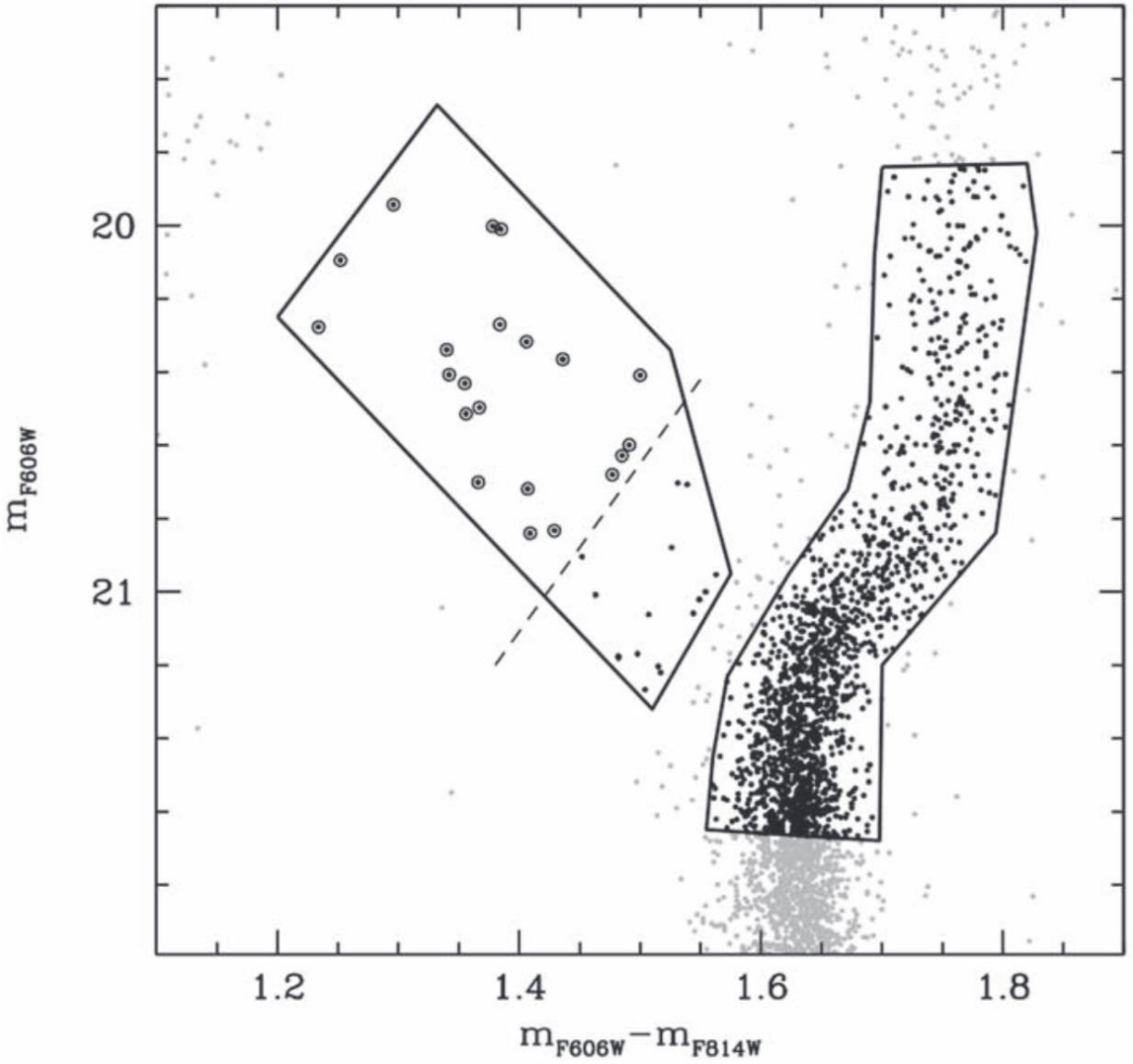

Fig.4 PM-cleaned CMD of NGC 6256 (gray dots) with 37 BSSs and 1585 reference stars in black.

Double Sequence of BSSs

- **Visual inspection** (Two distinct sequences).
  - **Blue Sequence:** narrow, 21 stars.
  - **red Sequence:** more sparse, 16 stars.
- **Statistical Validation.**
  - Method: Measured color distance of each BSS from the blue sequence ridge line.
  - Result: **Bimodal distribution** with two peaks separated by ~0.1 mag.

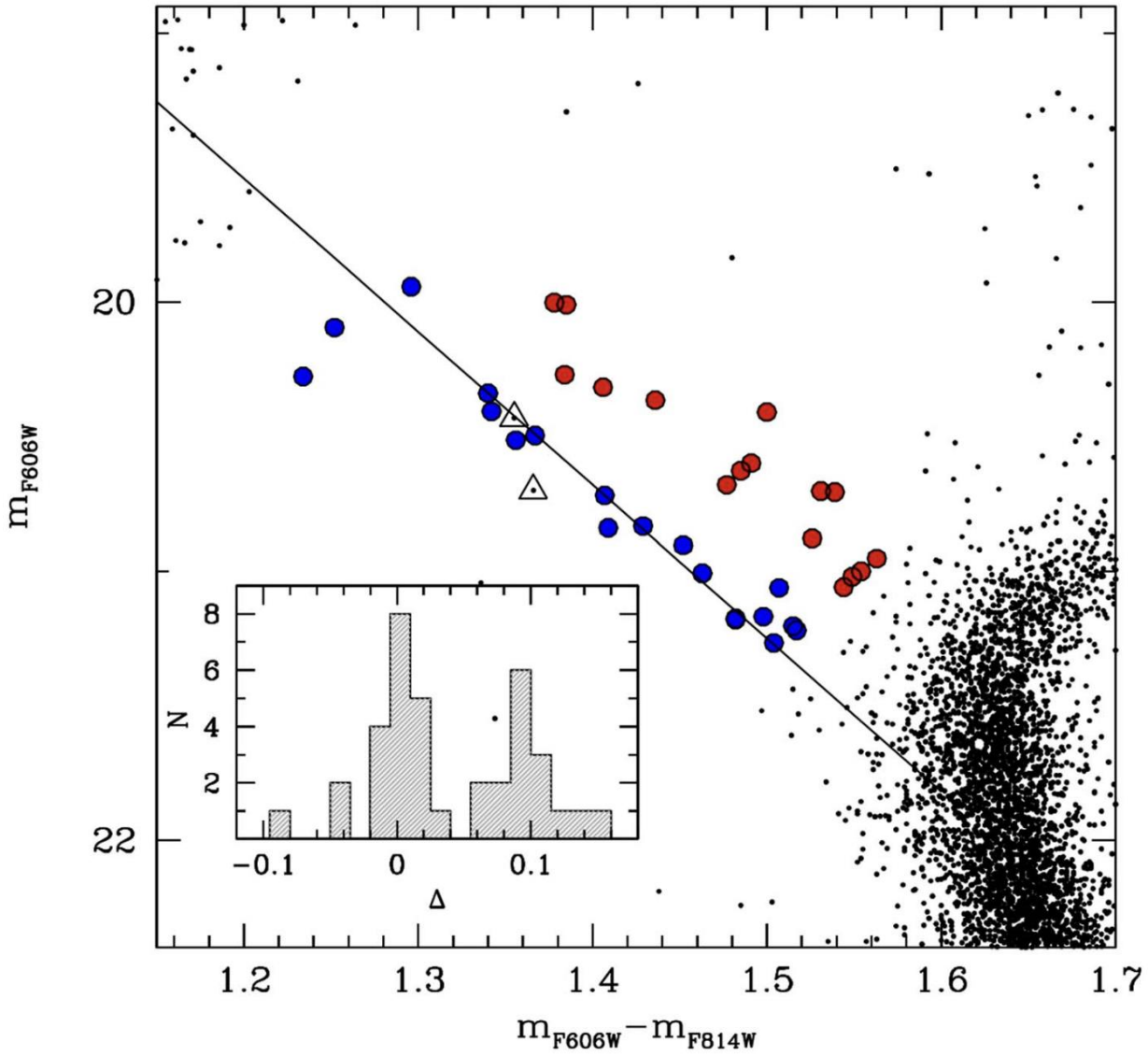

Fig.5 PM-selected CMD zoomed into the BSS region, with the BSSs aligned along blue and red sequence.

Double Sequence of BSSs

- **Physical Origin:**
- **Blue Sequence (Collisional):** 1) Matches impressively with **1 Gyr collisional isochrones** (Sills et al. 2009); 2) formation in a recent cluster core-collapse event.
- **Red Sequence (Mass transfer):** 1) Well reproduced by the locus of equal-mass binary systems; 2) Consistent with the standard **MT formation** scenario.
- Verify contamination from variable stars (e.g., W-Uma binaries).
- 2 BSSs show significant intrinsic variability.
- Don't alter conclusion of the collisional origin for the blue sequence.

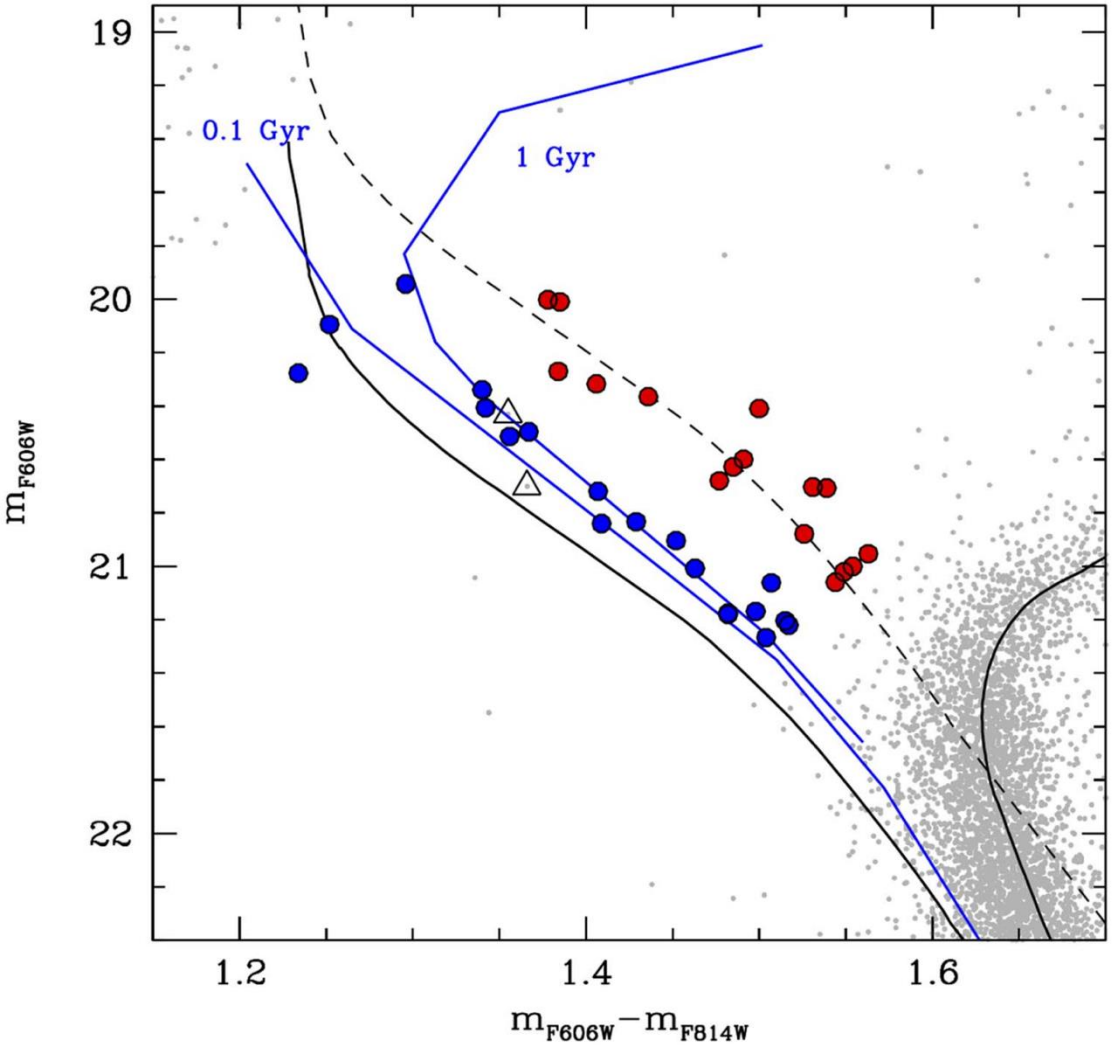

Fig.6 As in Figure 5, but with models superposed. The black solid lines are standard isochrones at 1 and 13 Gyr.

Measuring Dynamical Age from "Dynamical Clock"

- **Dynamical Clock:** empirical measurement of the cluster dynamical evolution level based on the observational properties of BSSs.
- ➢ A^{+}_{rh} **(measure the segregation level of BSSs):** defined as the area between the cumulative radial distributions of BSSs and reference stars within half-mass radius from the center.
- ➢ The value of A^{+}_{rh} is among the largest determined so far; consistent with NGC 6256 as a PCC cluster.

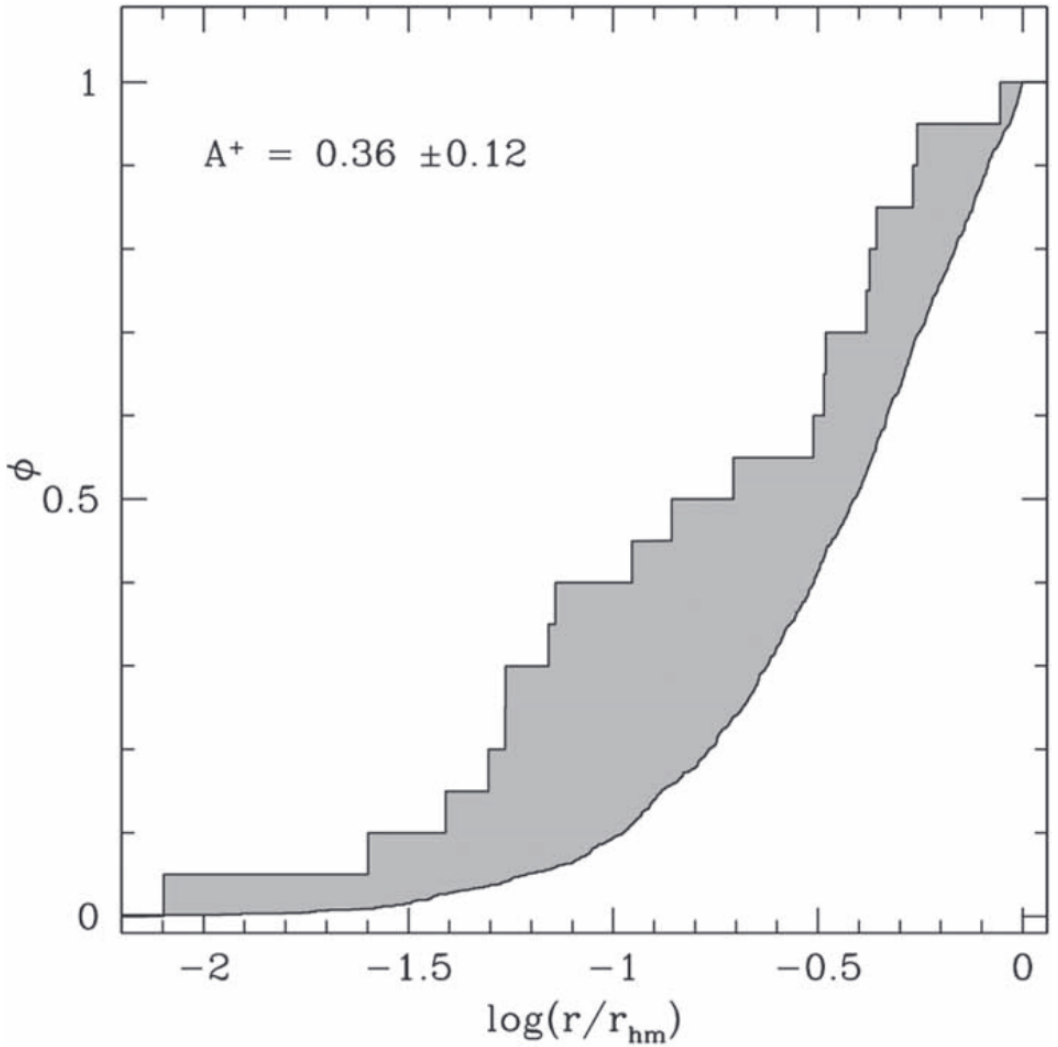

Fig.7 Cumulative radial distributions of the 20 bright BSSs (upper line) and the 1368 reference stars (lower line).

Summary

- **PCC phase: found a steep cusp with a power-law slope α_{cusp}** = -0.89.
- A_{rh}^{+} (0.36 $\pm$ 0.12): very high segregation level of the BSS population.
- The distribution of BSSs in CMD is characterized by a collimated blue sequence and a red more sparse sequence.
- Blue sequence are mostly formed through collisions in a recent and short-lasting event (the cluster CC), while red sequence are likely formed through MT in binary systems.
- Segregation level of BSSs is a powerful dynamical diagnostic also of cluster in a very advanced stage of dynamical evolution.

Thanks!