Disentangling Stellar Populations in Globular Clusters with MORFEO-MICADO@ELT to unveil their origins

D. Pérez-Millán, F. Annibali, C. Arcidiacono, L. Schreiber, G. Fiorentino,
and the MORFEO team

INAF
ISTITUTO NAZIONALE
DI ASTROFISICA
OAS
BOLOGNA

Meeting della strumentazione ELT a guida italiana (MORFEO e ANDES)
May 13, 2025

ESO

Introduction

- Massive globular clusters (GCs) may represent the **remnant nuclei** of ancient **dwarf galaxies** stripped of their stellar and dark matter envelopes by tidal interactions with the host giant galaxy.
- To test this hypothesis, we search GCs for the presence of an internal **spread in age/chemical abundances**.
- This will prove that there was an epoch when the system was sufficiently massive (10^7 M⊙) to retain the ejecta of these very energetic polluters.
- Chemical spread can be revealed in the CMD as a **color spread** in the Red Giant Branch.
- **Massive GCs** are relatively **rare** in the Local Group. We study GCs in Cen A.
- MORFEO+MICADO@ELT will greatly enlarge the volume where GCs can be **resolved** into **individual stars**.

Goal: We aim to recognise different stellar populations in the CMD of GCs in Cen A.

Centaurus A (NGC 5128) galaxy

- ✦ 321 GC candidates (Dumont+, 2022)
- ✦ 57 luminous GC confirmed
- ✦ GC with very high mass-to-light ratios
- ✦ Proximity: 3.8 Mpc
- ✦ Color bimodality in GCs (both metal-poor (blue) and metal-rich (red), different formation histories.
- ✦ Galaxy merger evidence

GCs in Cen A will be resolved by MORFEO+MICADO ~5 times better than HST resolves M31 GCs.

Outline

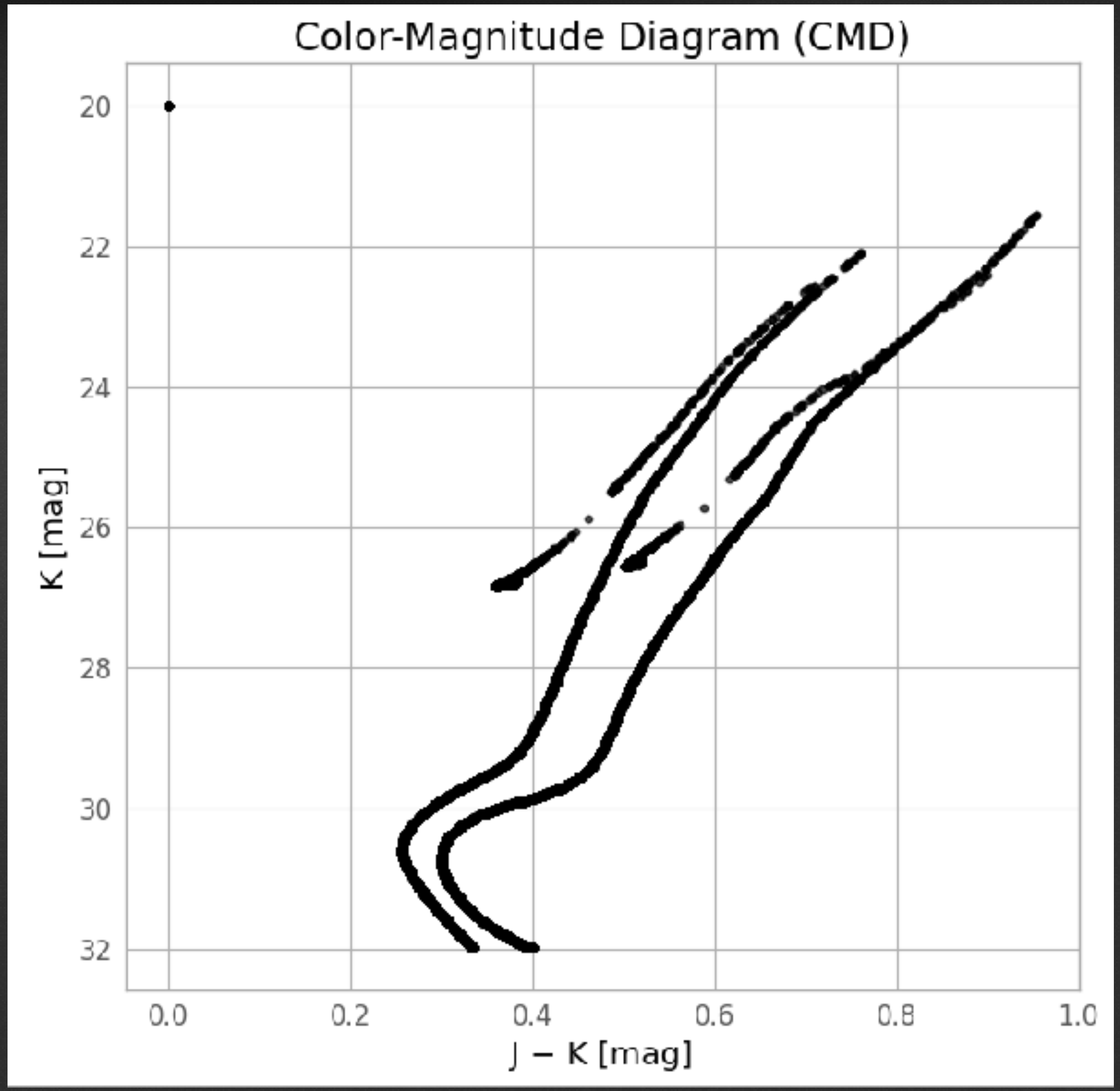
1. Generate **synthetic models** for the stellar populations.
2. **Distribute stars** according to a **King profile**, using observed GC angular sizes in Cen A (Dumont+ 2022).
3. Add some **foreground stars** from TRILEGAL to facilitate PSF extraction and magnitude calibration.
4. **Simulate images** with ScopeSim (PSFs generated by Tiptop).
5. Analyse images and perform **photometry** using StarFinder.
6. **Compare photometry**-derived CMDs with the initial synthetic models.
7. Refine the results based on the comparison.

1. Star catalogue (synthetic models)

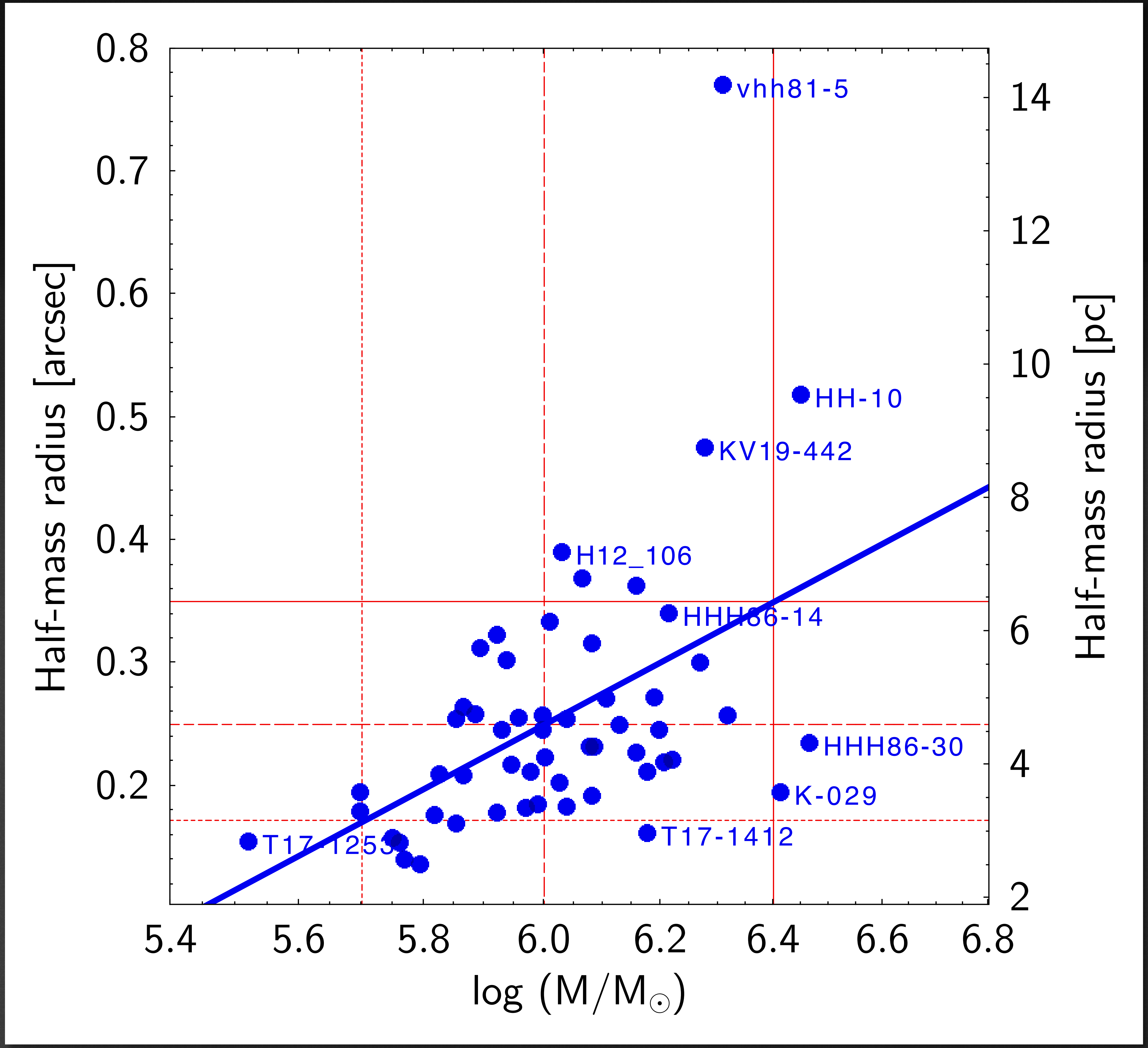
PARSEC v1.2S tracks:

- 10 Gyr, [M/H] = -1.0
- 12 Gyr, [M/H] = -1.5
- Total log M/M$_\odot$ = 6.4, …, 6.0

Two isochrones



Globular clusters in Centaurus A (Dumont+, 2022)



Angular size

Stellar mass

2. Star distribution

King profile

$$\Sigma(R) \propto \left(\frac{1}{\sqrt{1+(R/r_c)^2}} - \frac{1}{\sqrt{1+(r_t/r_c)^2}} \right)^2$$

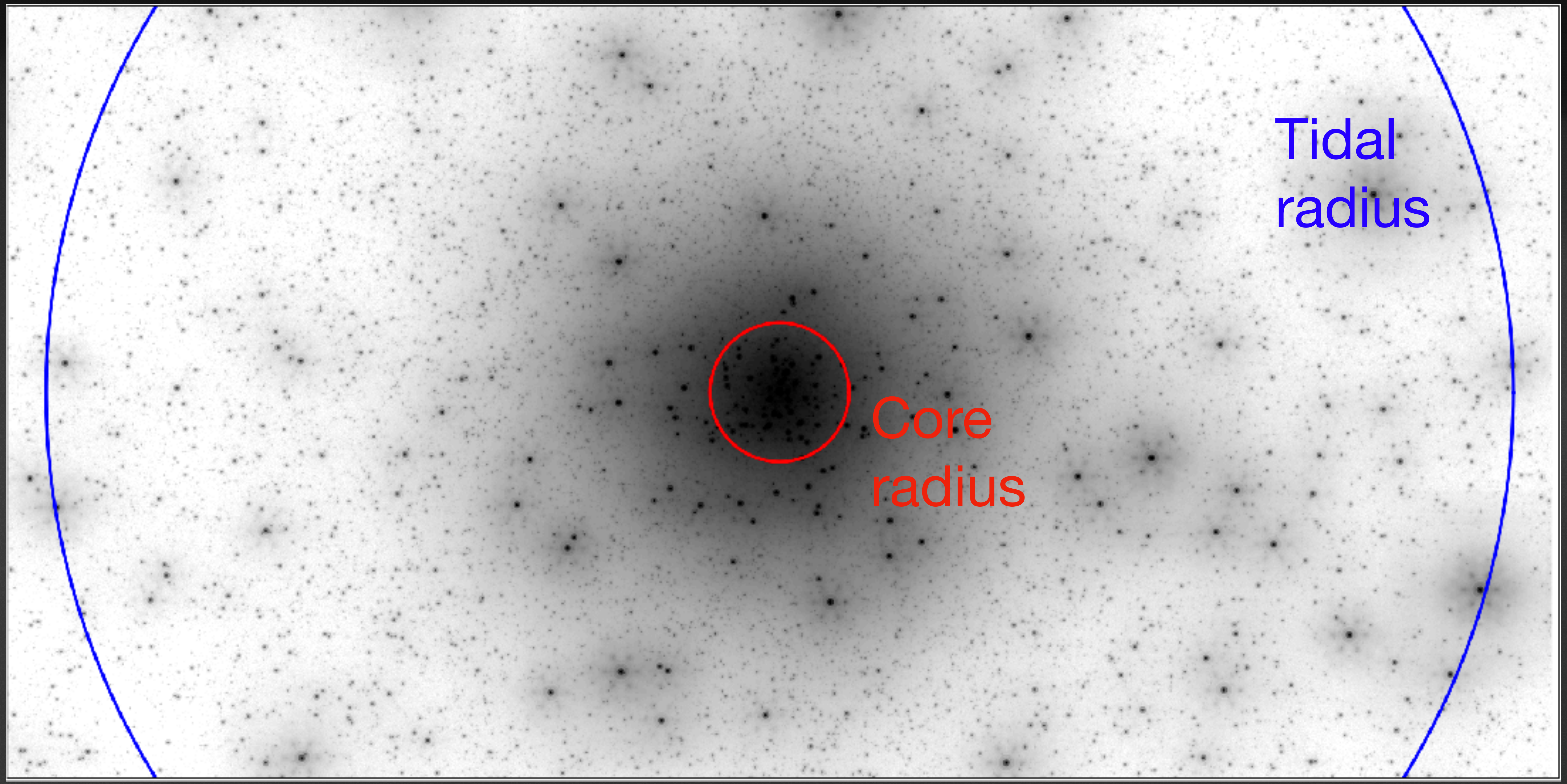
r_c: core radius

r_t: tidal radius

c: concentration

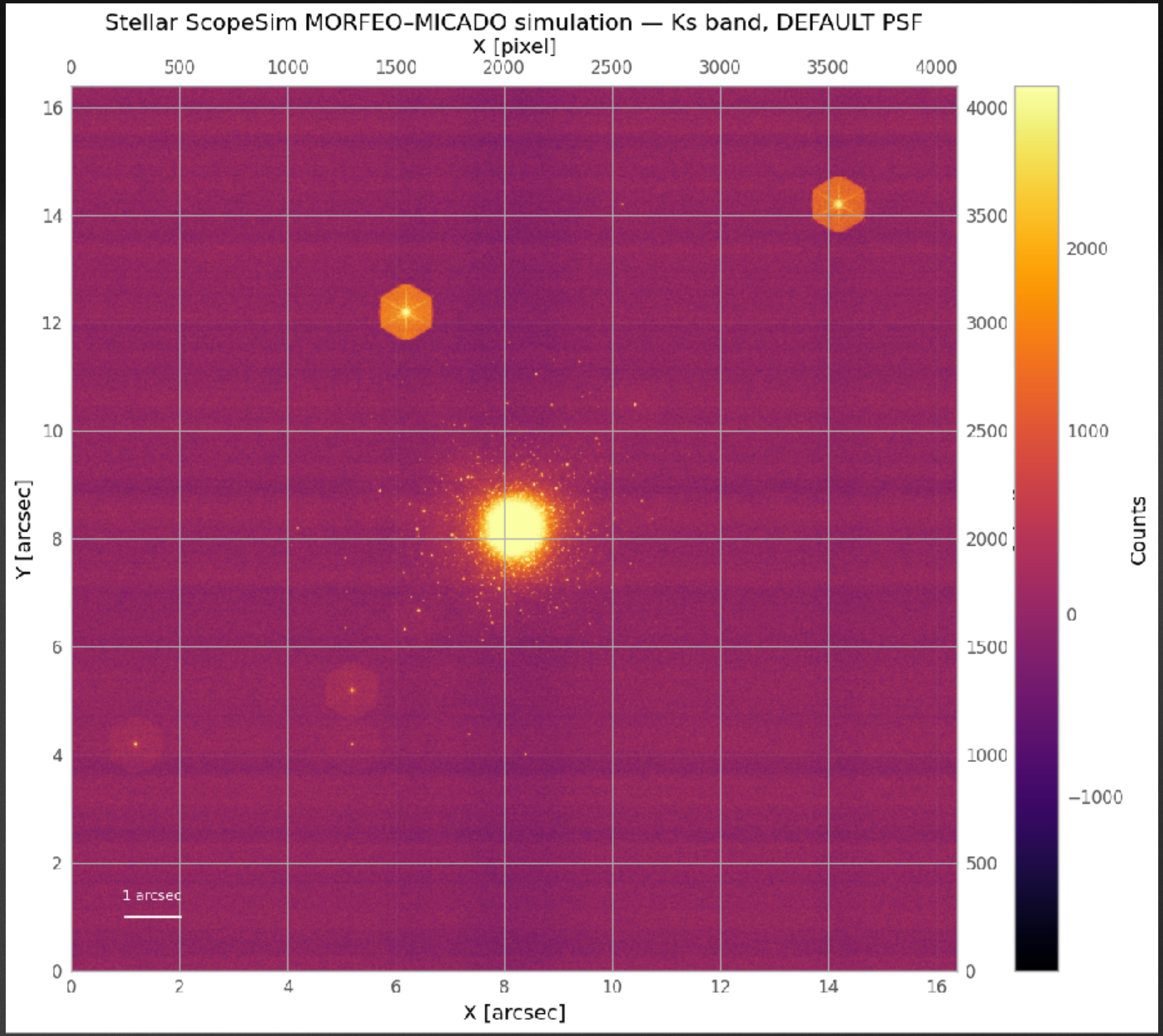
$c = \log(r_t / r_c) = 1.4$ (typical)

Nuclear GC in **NGC 300**



Taken from Gullieuszik+, 2014

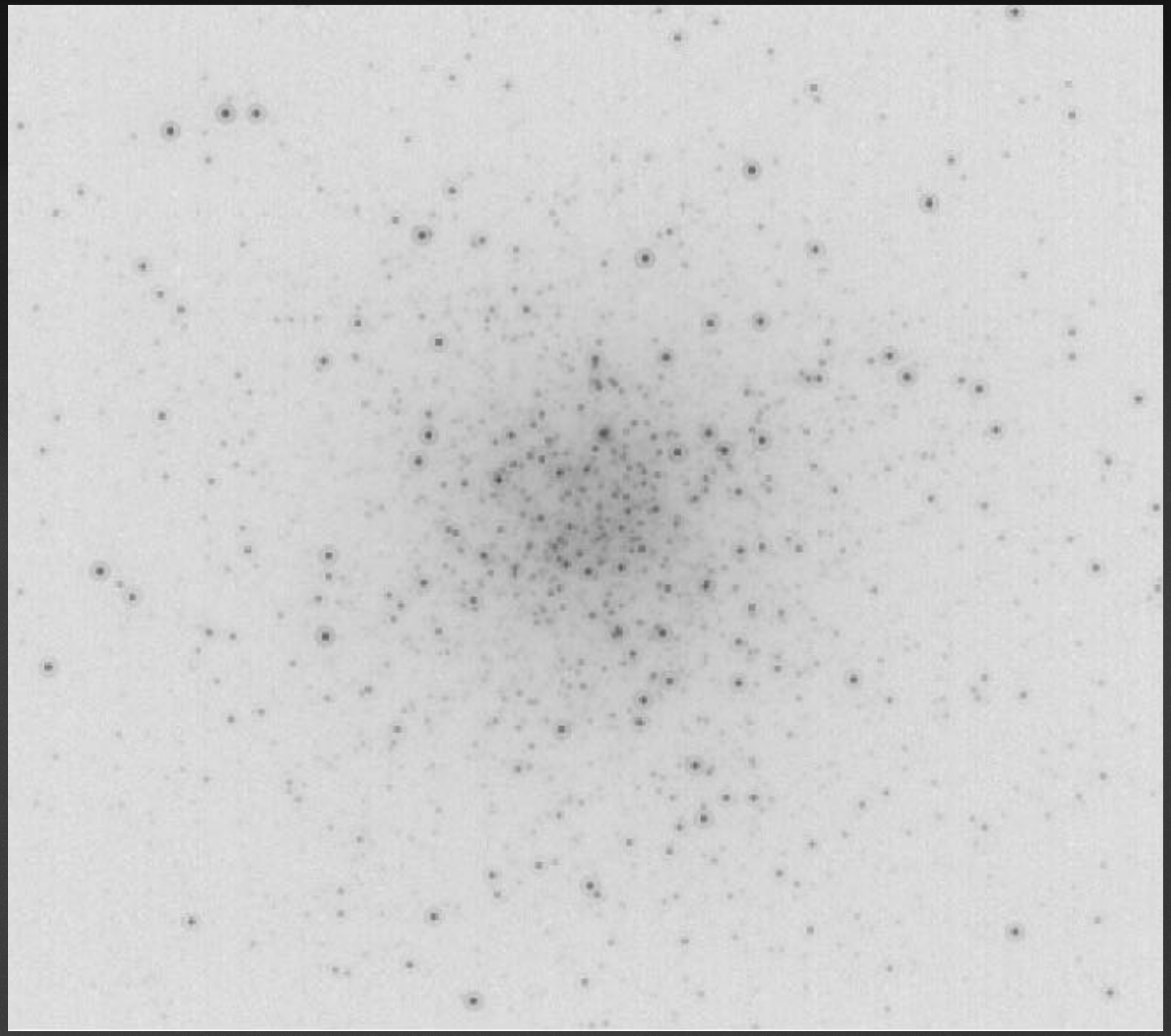
3. Add foreground stars from TRILEGAL



These stars are used later to extract PSF and calibrate magnitudes

4. Simulating images with Scopesim

MCAO observations: IJHK bands

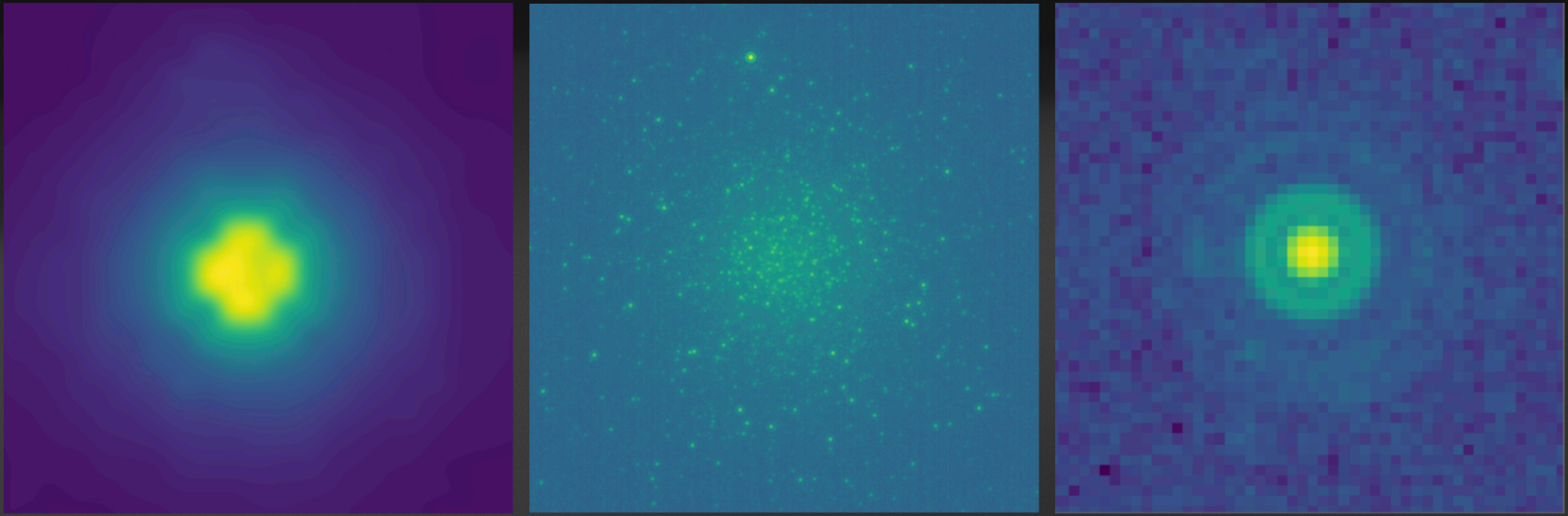


GC: HH-10, K image zoomed

- ✳Utilizing a standard PSF generated from Tiptop
- ✳Average atmospheric (seeing) conditions
- ✳Three natural guide stars (NGS) configuration
- ✳Total exposure: 1 hour

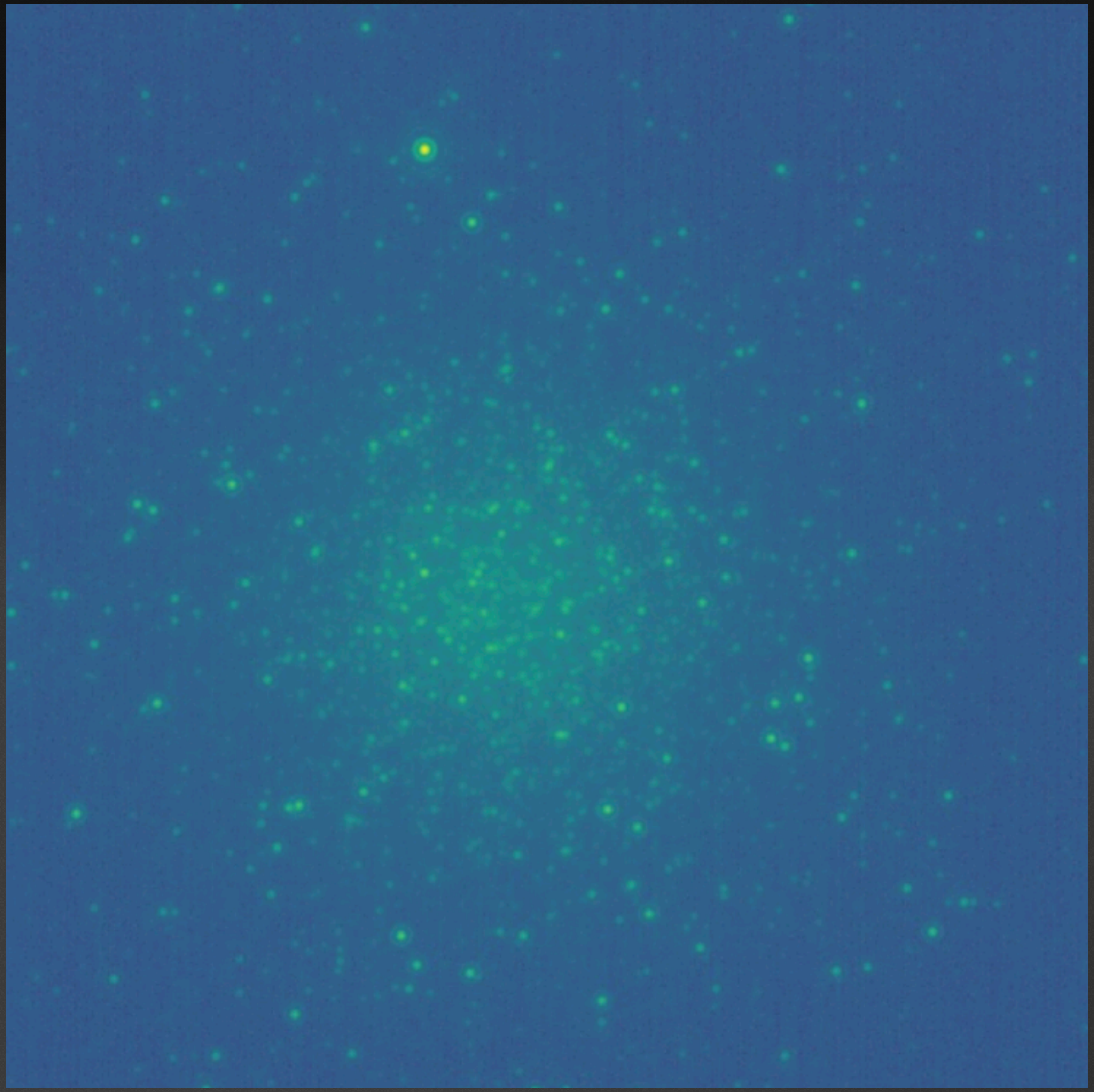
5. Photometry with StarFinder

Background | Noise | PSF

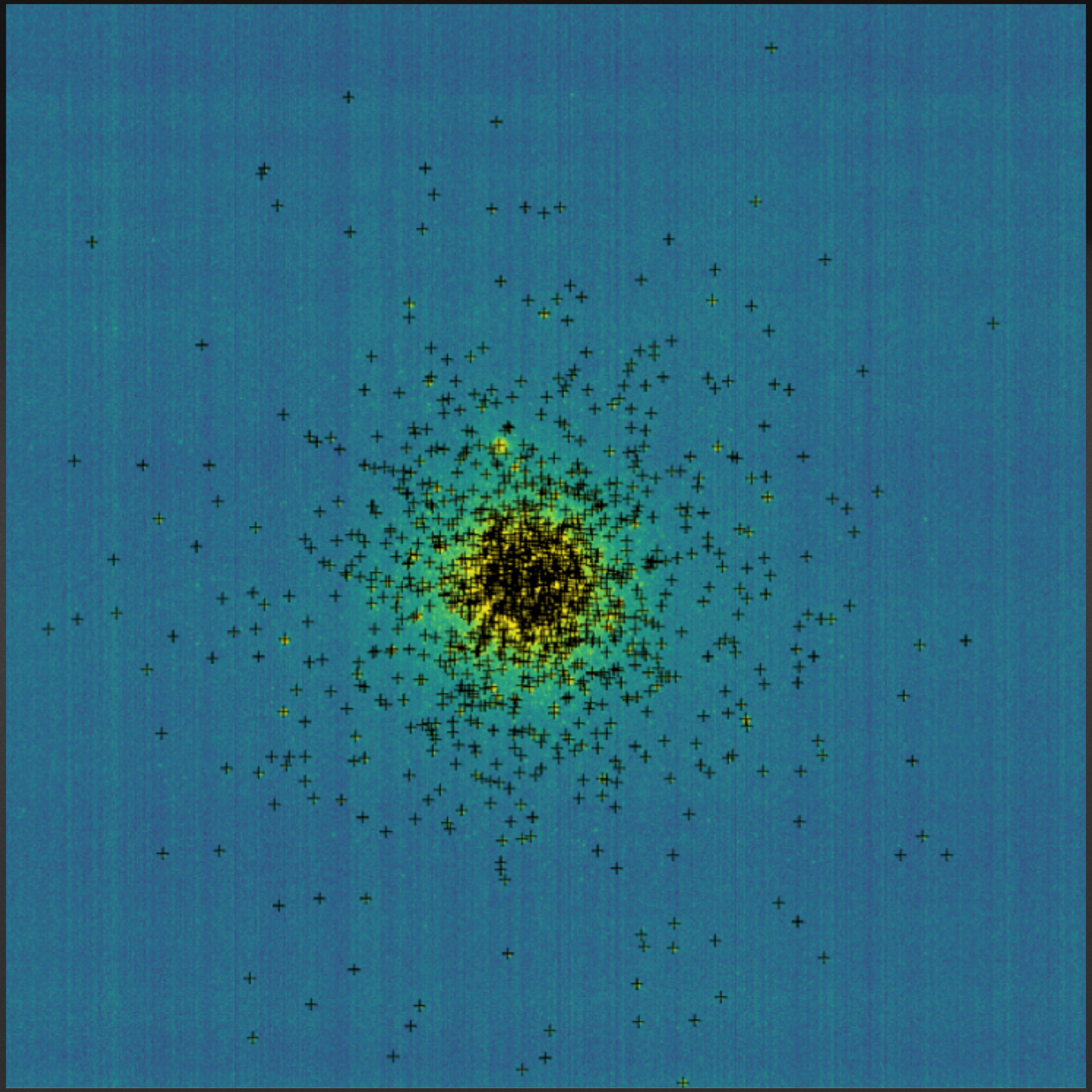


These three can be given as an input, or estimated by StarFinder from the image

Input image (zoomed)

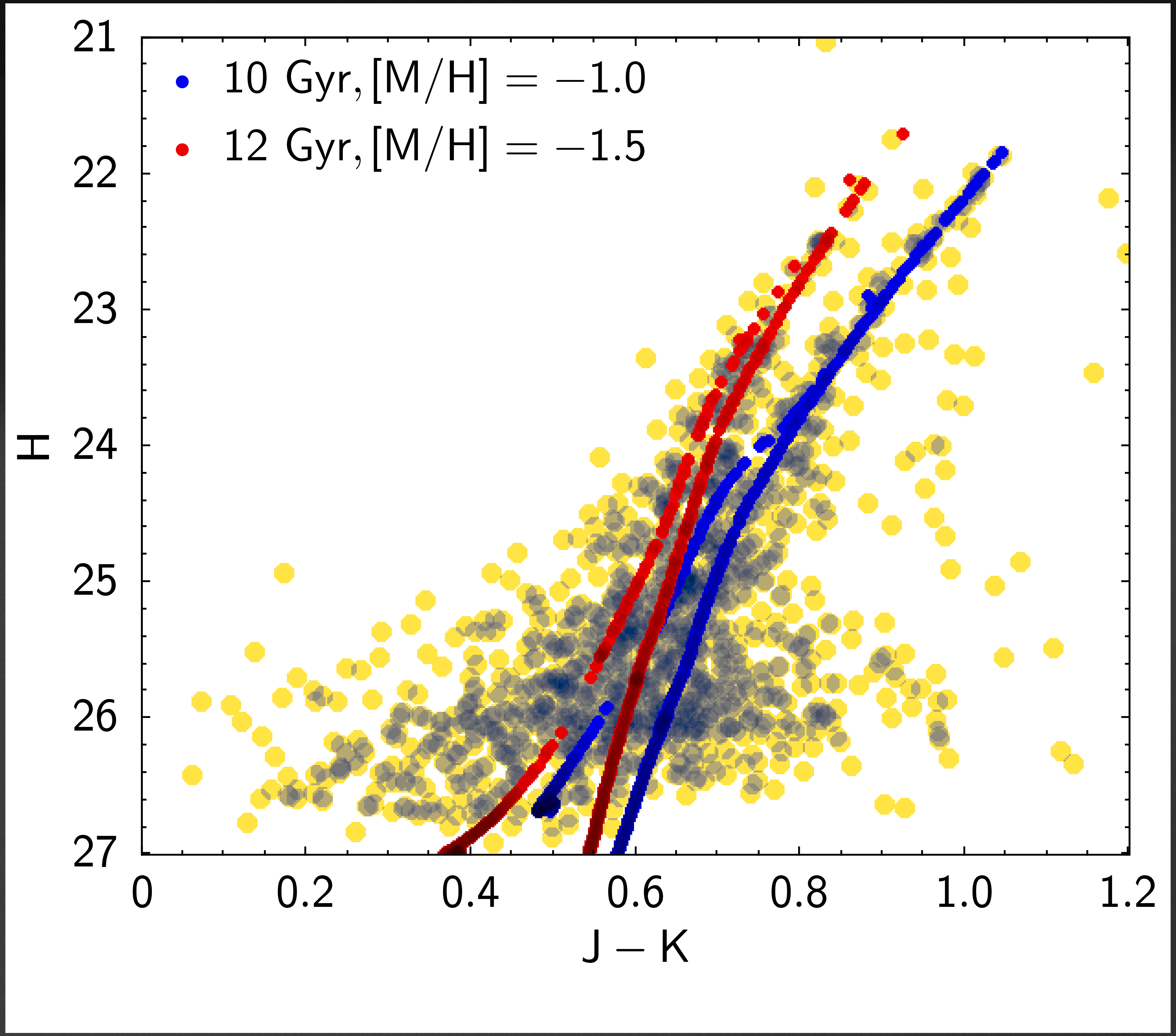


Stars detected

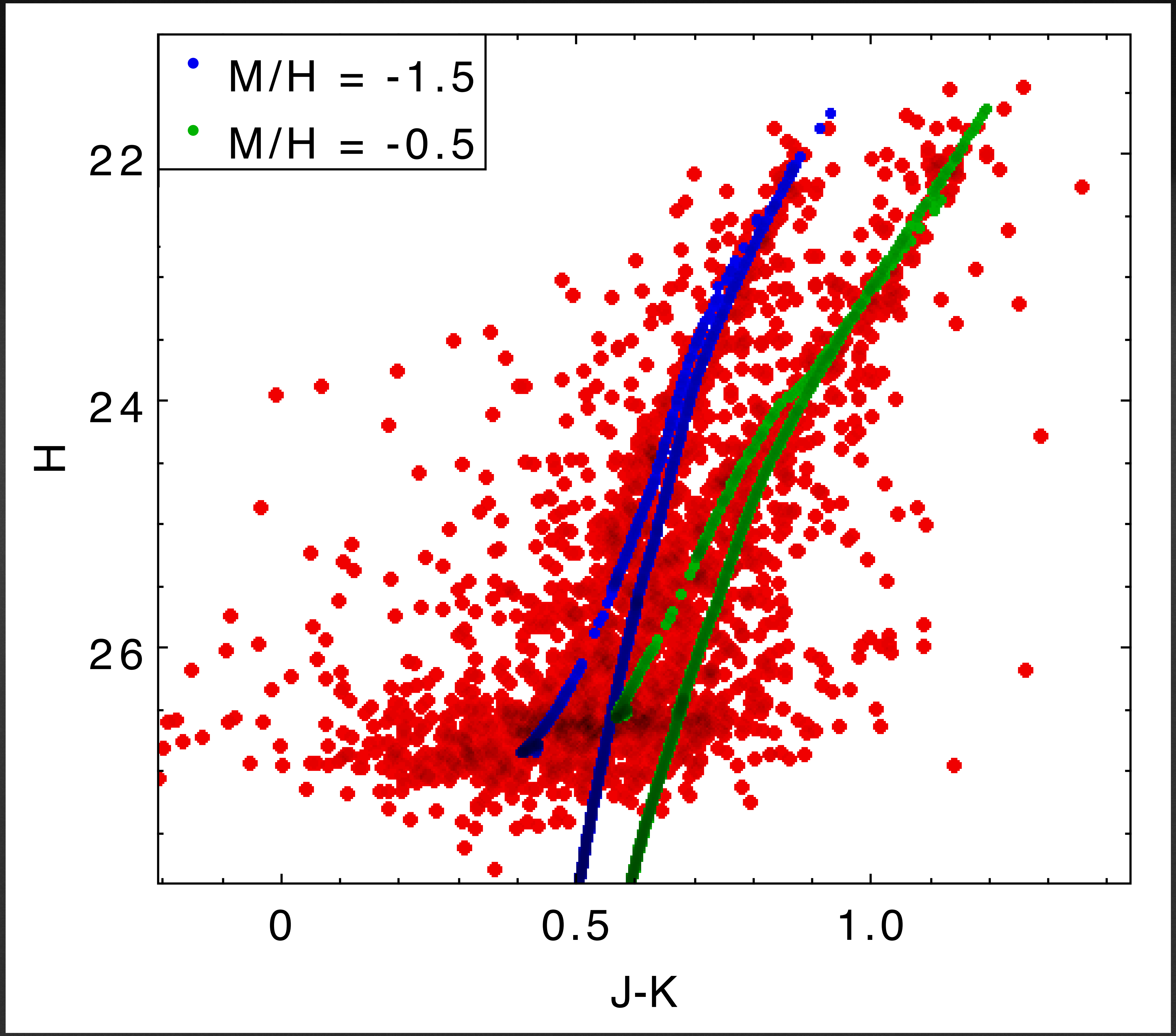


6. Compare photometry-derived CMDs with models

HH-10



HHH86-30



Conclusions

- ✓ We are able to distinguish both stellar populations in GCs.
- Next…
  - Inject PSF stars from real catalogues
  - Use continuum star formation (rather than a single burst model)
  - Extend the analysis to GCs with lower stellar masses (log $M/M_{\odot} \sim 6$)
  - Try with different (lower) exposure times
  - Test the methodology on more distant GCs

Thanks