The detectability of Extragalactic Globular Clusters in the Euclid survey

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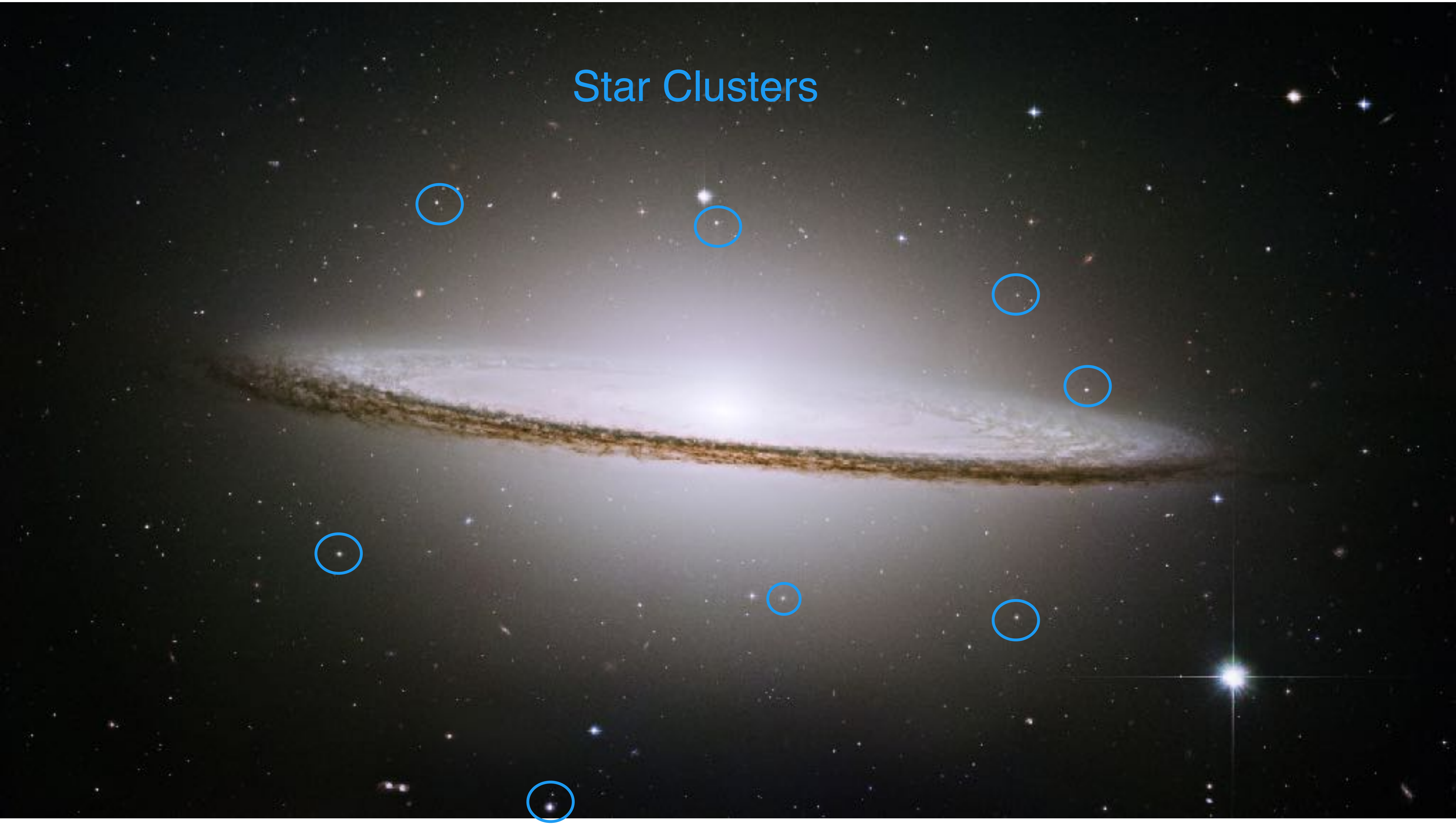
Michele Cantiello, Pierre-Alain Duc, Annette Ferguson, Patrick Hudelot, Pratik Lonare, Francine Marleau, Achille Nucita, Marina Rejkuba, Erik Romelli, Teymoor Saifollahi, Rubén Sanchez-Janssen, Jenny Sorce, Crescenzo Tortora + all of EGC WP8 team

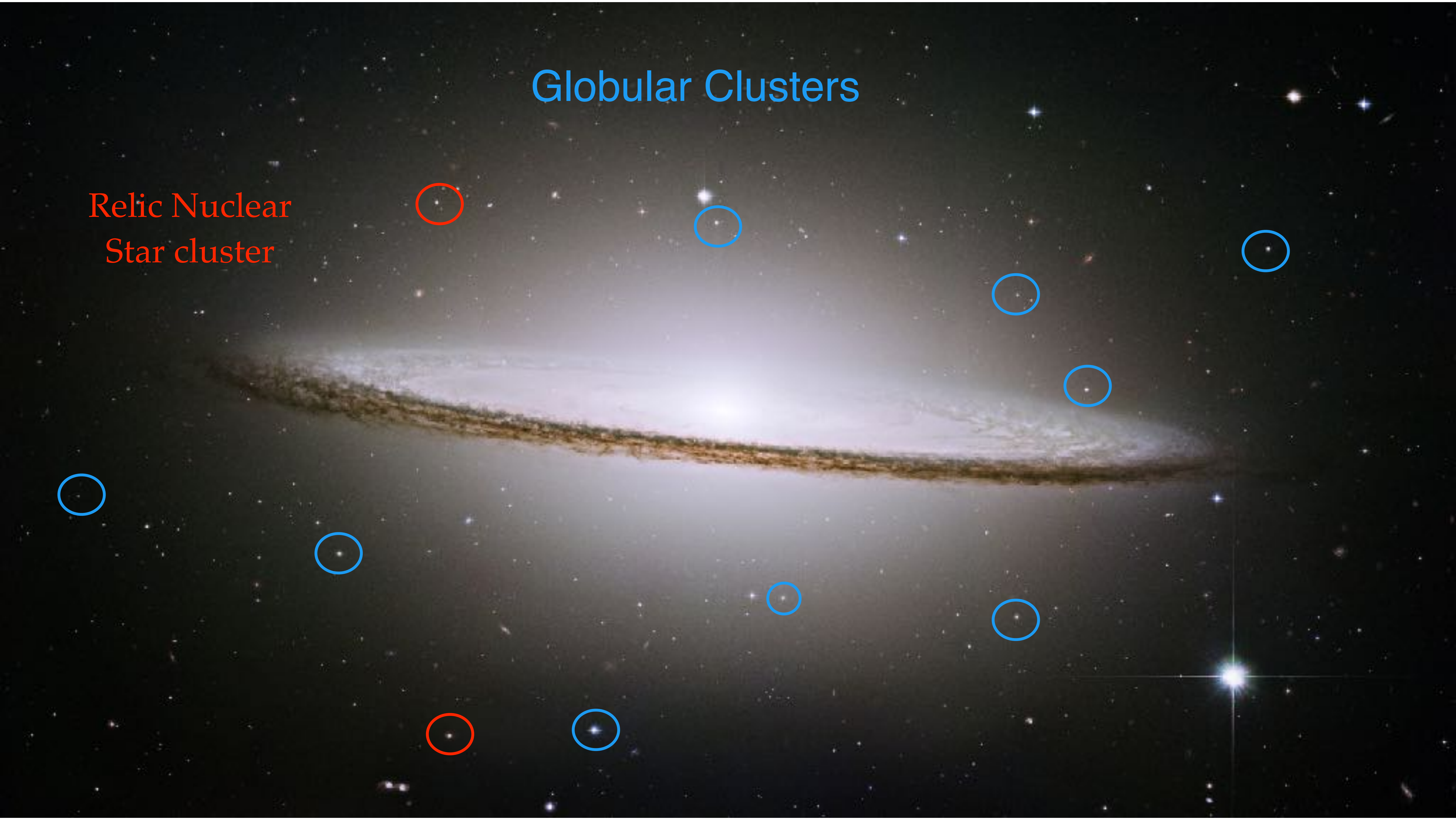
GLOBULAR CLUSTERS (GCS)

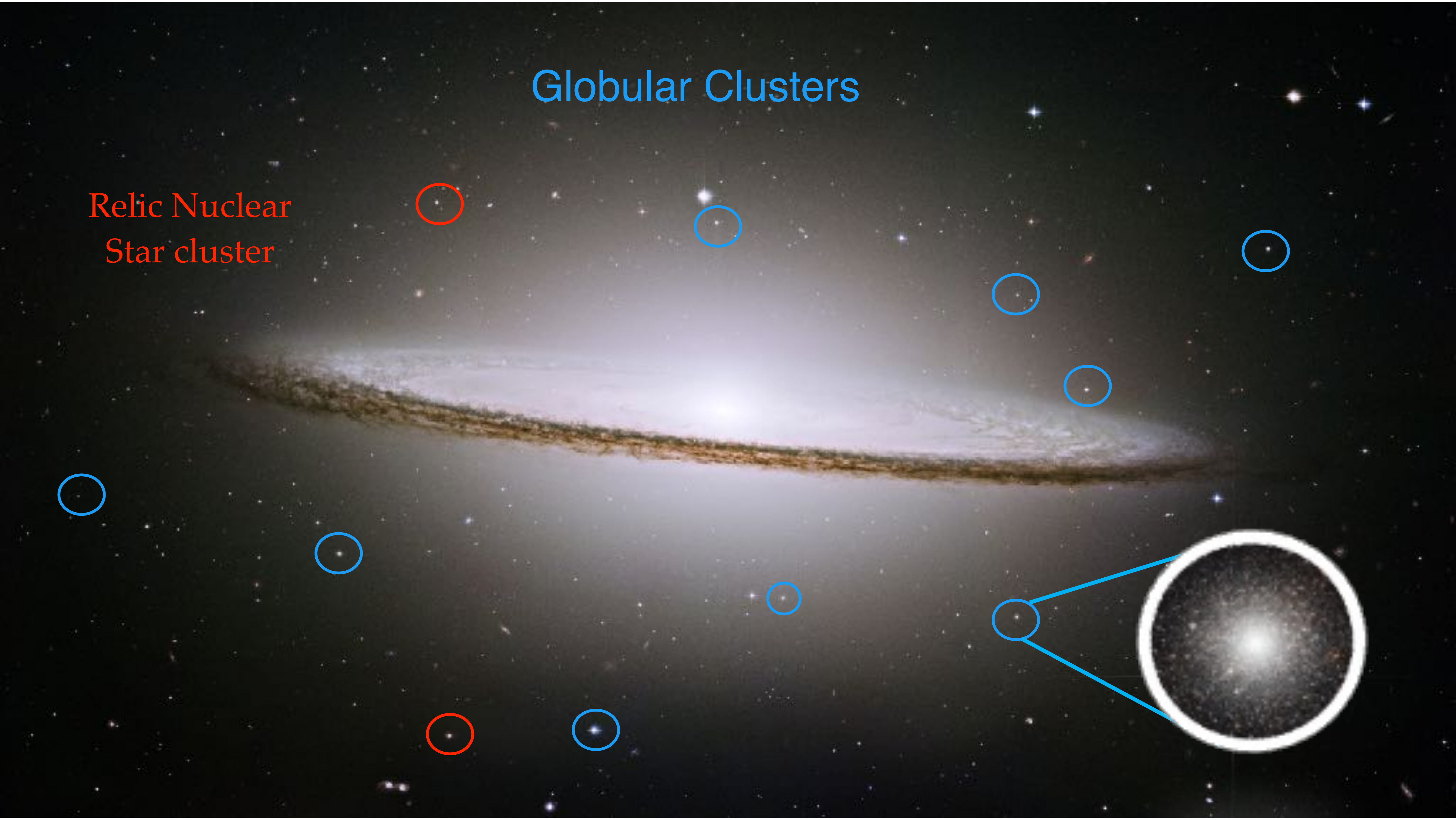
1. Formed in a single stellar burst
2. 10^4-10^7 solar masses packed into a couple pc of volume
3. Exist in virtually all galaxies

M54 - Nucleus of Sagittarius

M15 - star cluster


Star Clusters


Globular Clusters
Relic Nuclear
Star cluster


Globular Clusters
Relic Nuclear
Star cluster

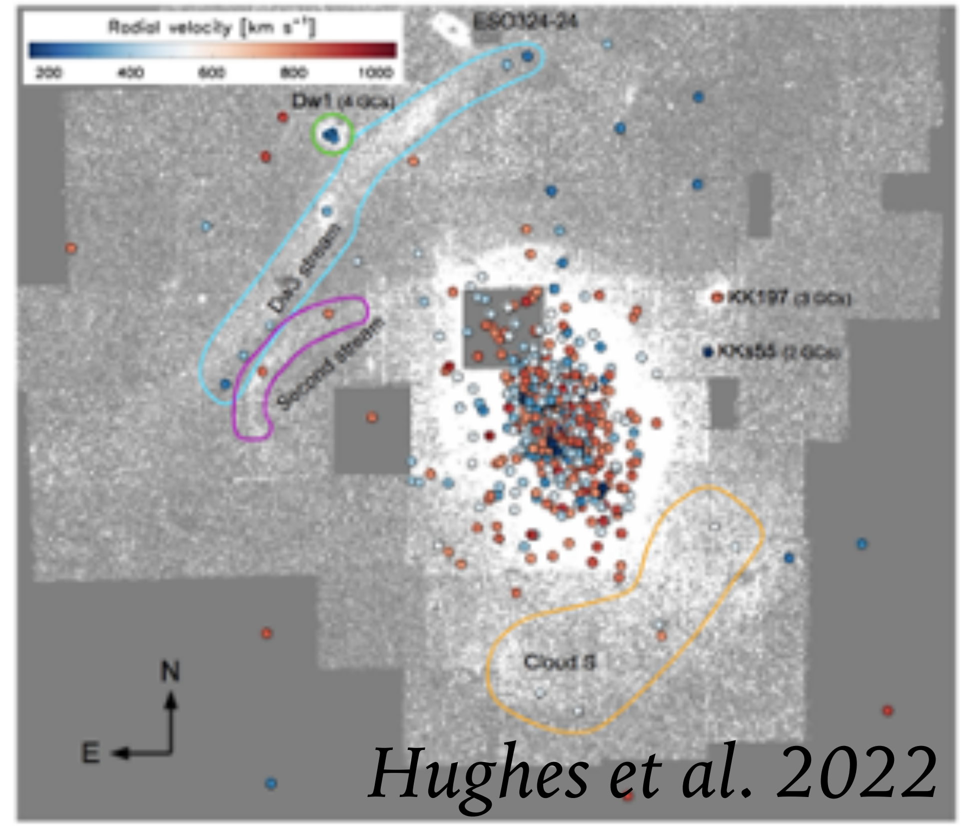
GLOBULAR CLUSTERS AS RELICS OF ACCRETION

Globular Clusters origins: in-situ formation and ex-situ through accretion from external galaxies

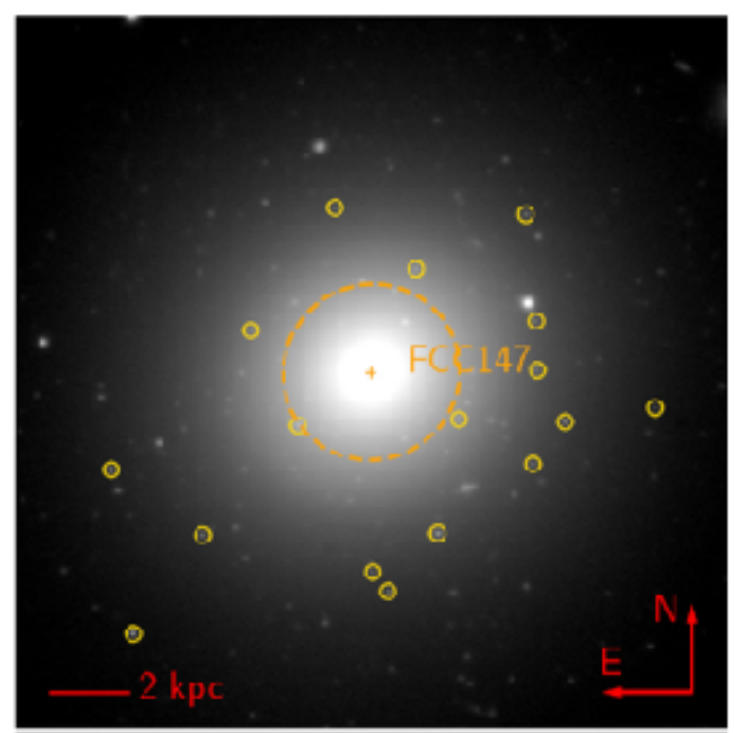
Tracing galaxy evolution:

1. Dark Matter distribution
2. Tracking substructure & tails

Understanding GC formation & evolution itself

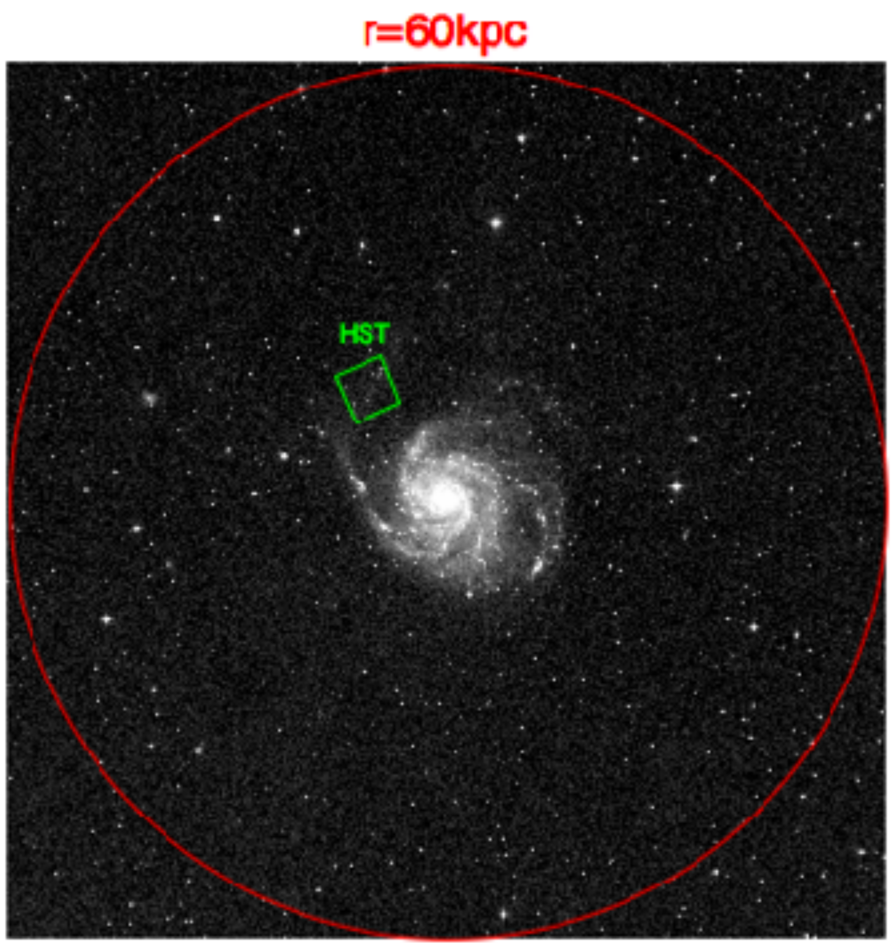


Hughes et al. 2022



Saifollahi et al. 2021 Fornax galaxy with GC & nuclei candidates

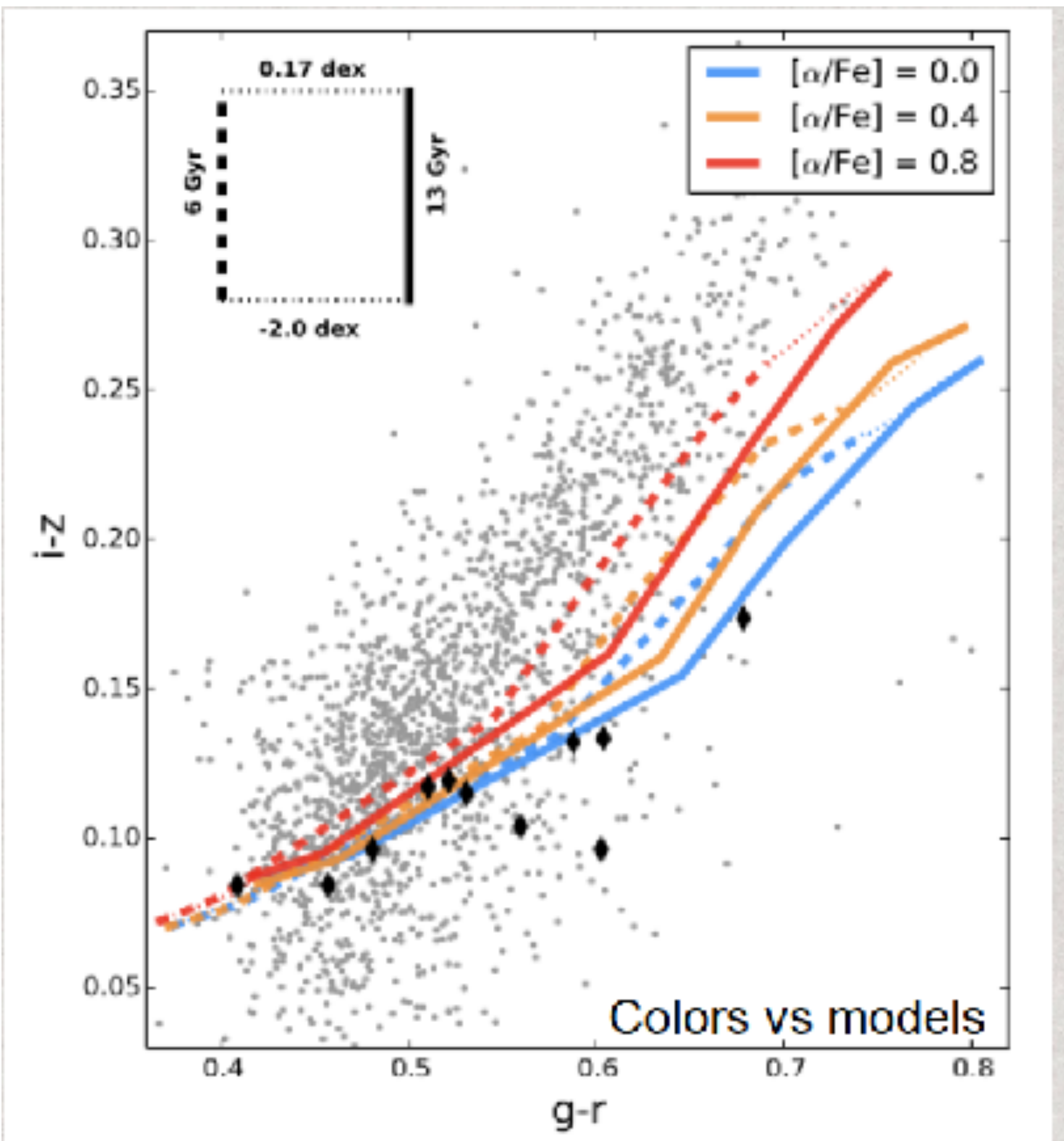
EUCLID FOOTPRINT + VIS RESOLUTION



M101 at 7Mpc ~ Halo 150kpc
Halo is 1+ degree on sky

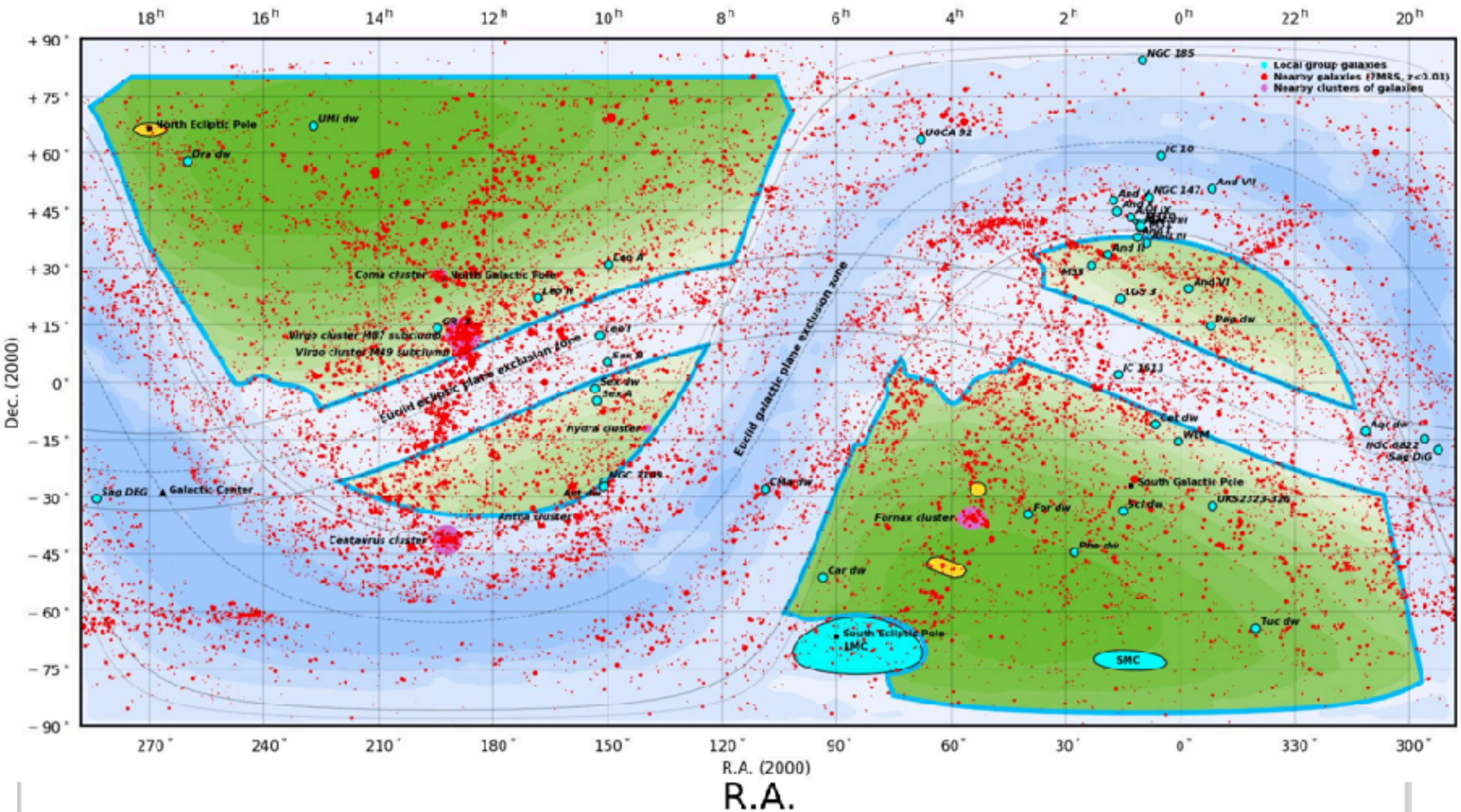
- HST & JWST have small FOV and can only study galaxy centers for GCs
- EUCLID'S large footprint + high spatial resolution of VIS enables detection of GCs in local Galaxies way beyond any current capabilities

DEEP AND HOMOGENOUS EUCLID PHOTOMETRY



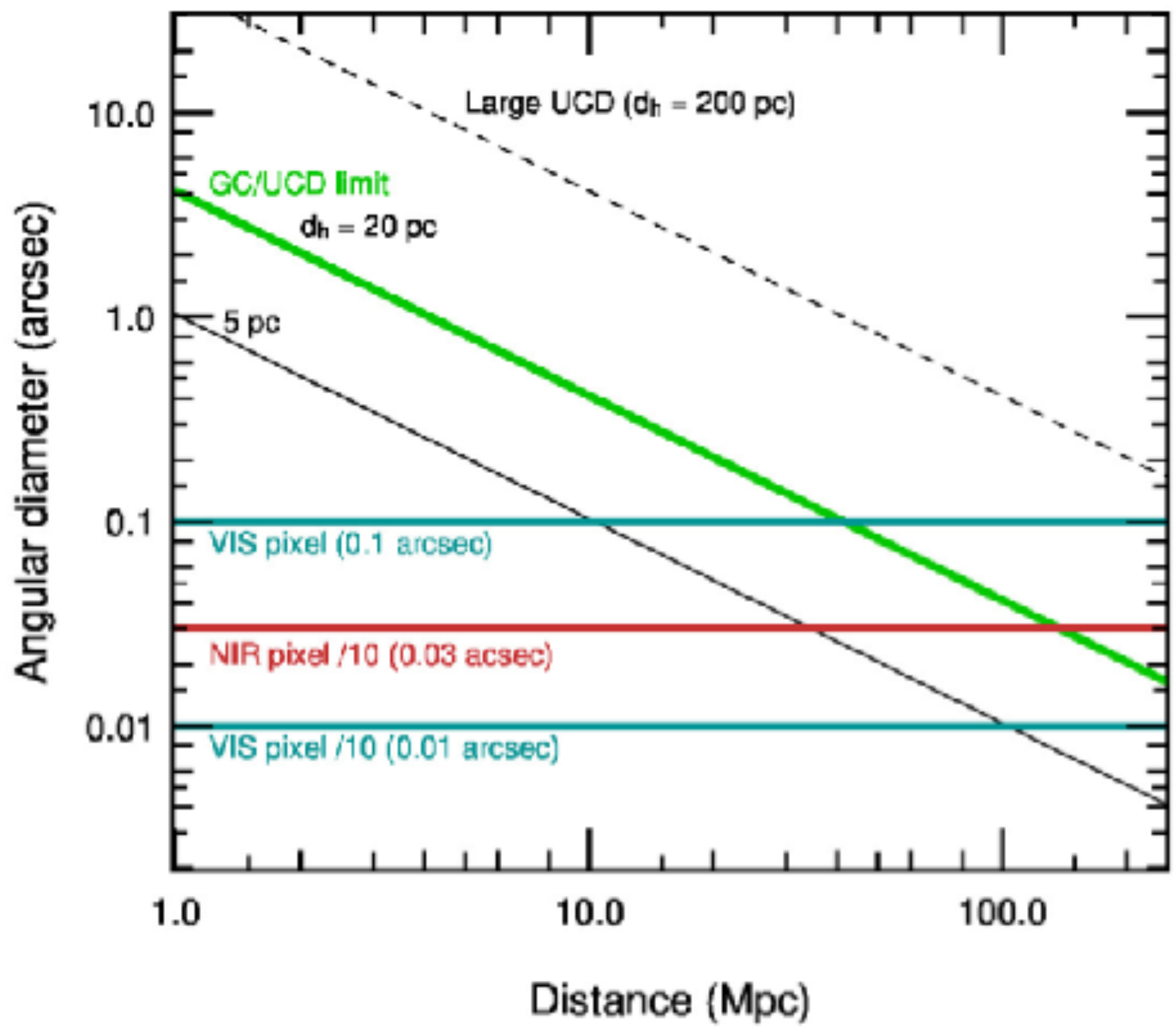
- **Currently**: Ground based photometry is inhomogeneous, has large errors and unknown systematics
- Effect of ages & abundances in color-colors diagrams are larger
- **Euclid**: offers possibility to recalibrate and improve our population models of GCs as legacy science with VIS & NISP photometry

WHAT LOCAL GALAXIES ARE IN THE FOOTPRINT?



Scaramella et al. 2021

THEORETICAL GC DETECTION LIMITS BASED ON SIZE



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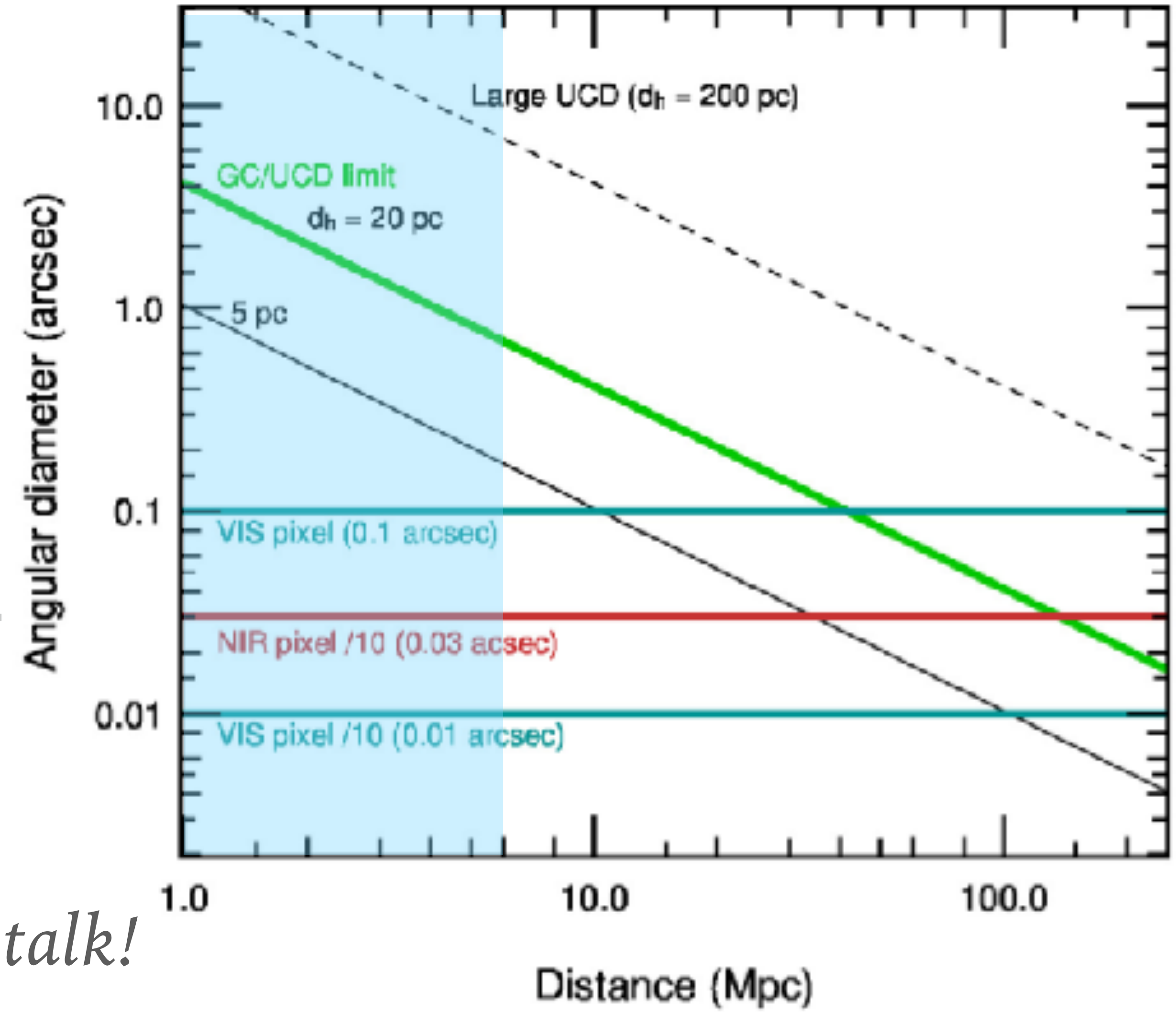

see A. Ferguson's talk!

1.) Resolved

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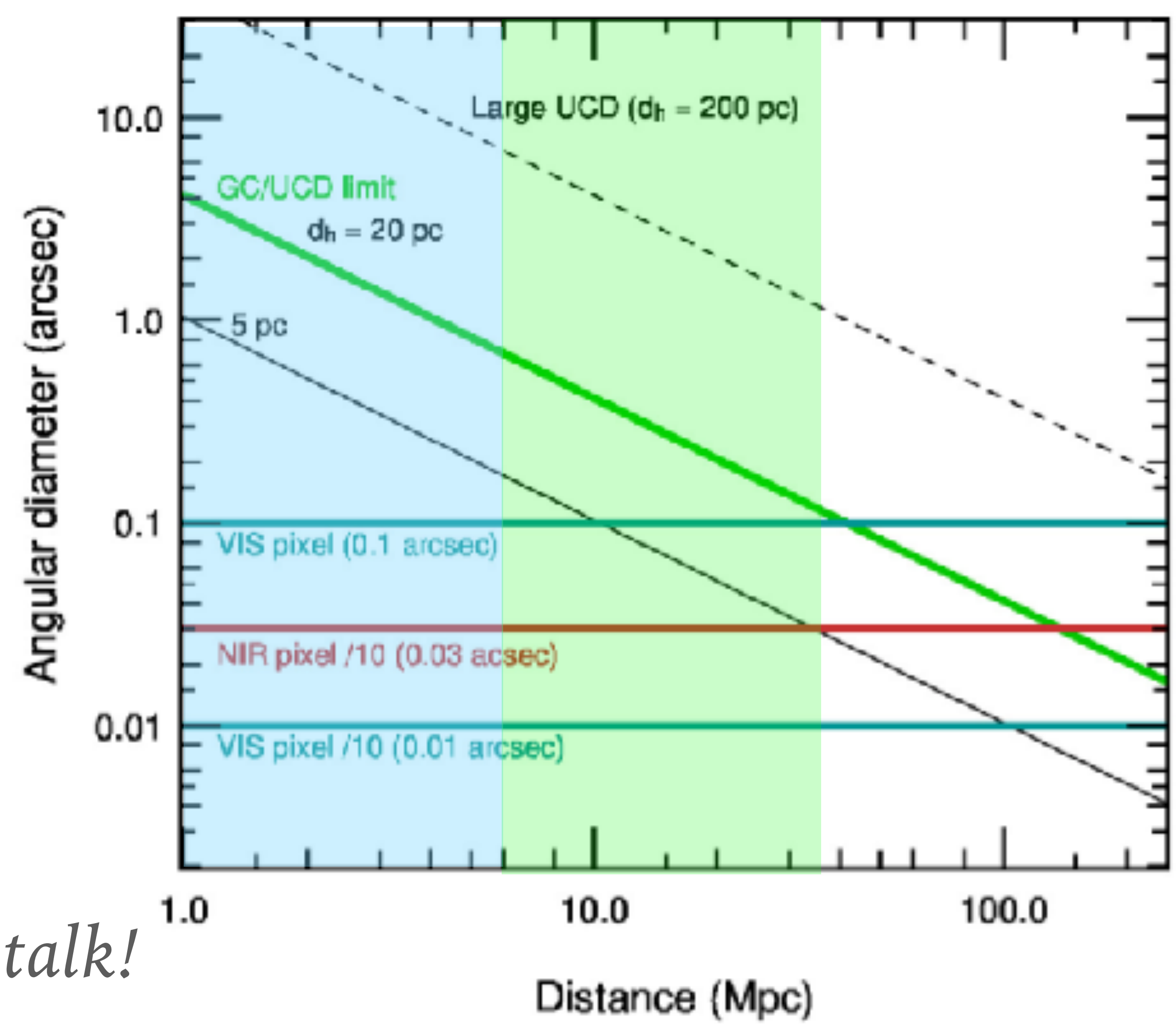

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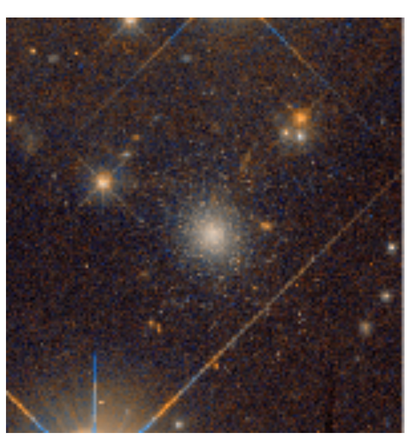

1.) Resolved

2) Size measurement possible

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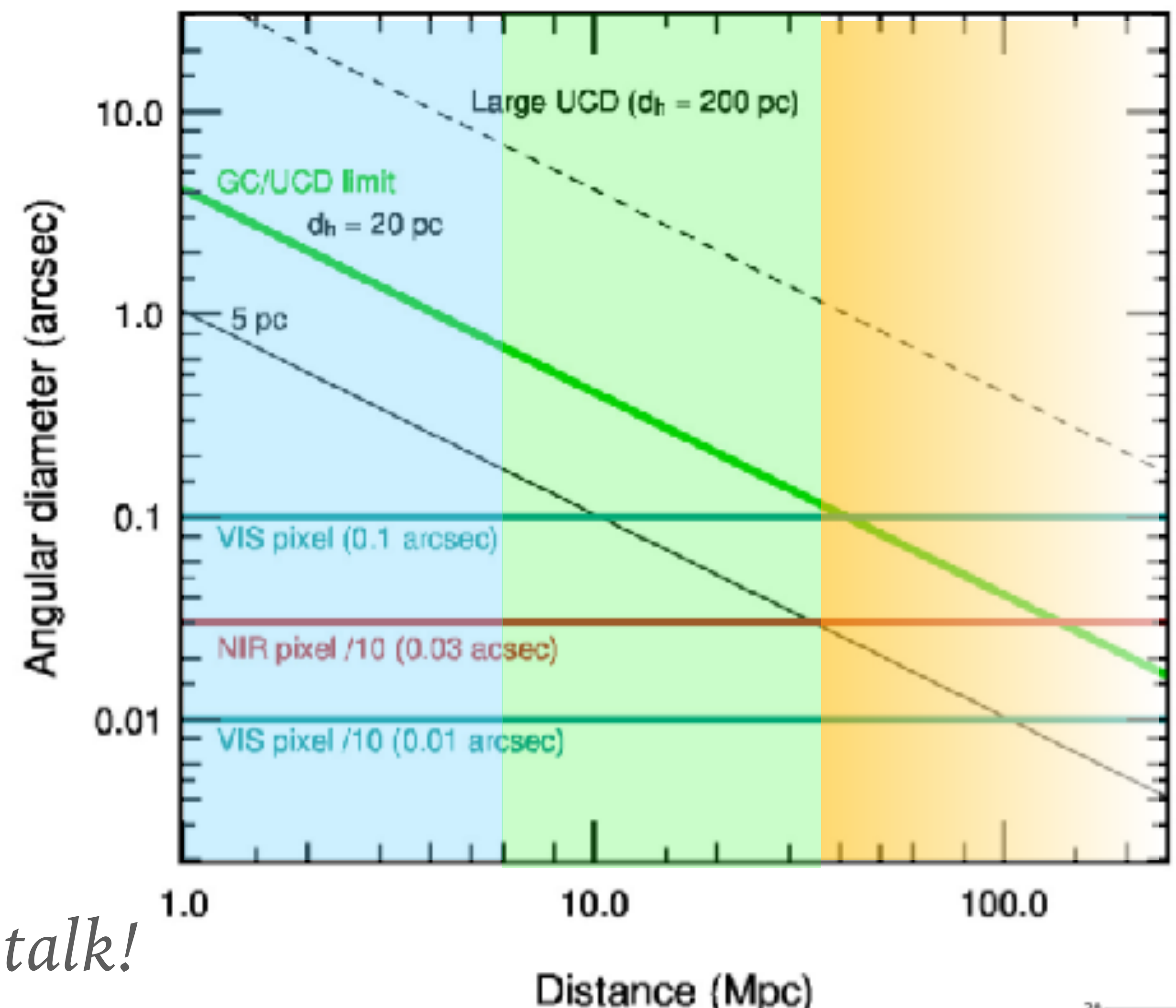

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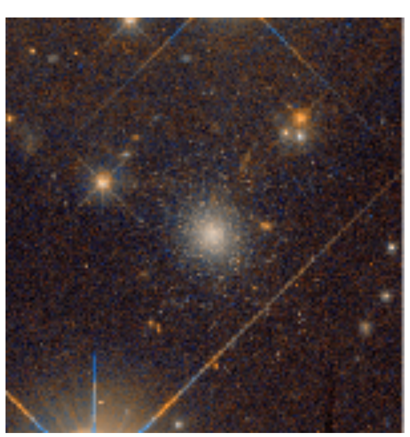
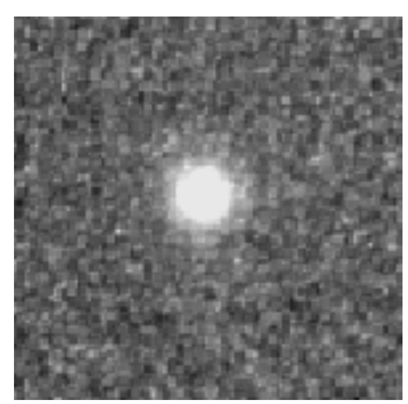
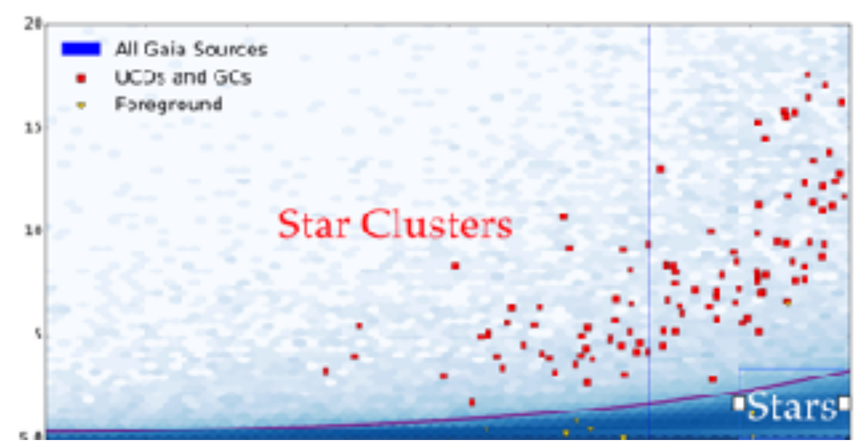


1.) Resolved



2) Size measurement possible



3.) Excess compared to PSF

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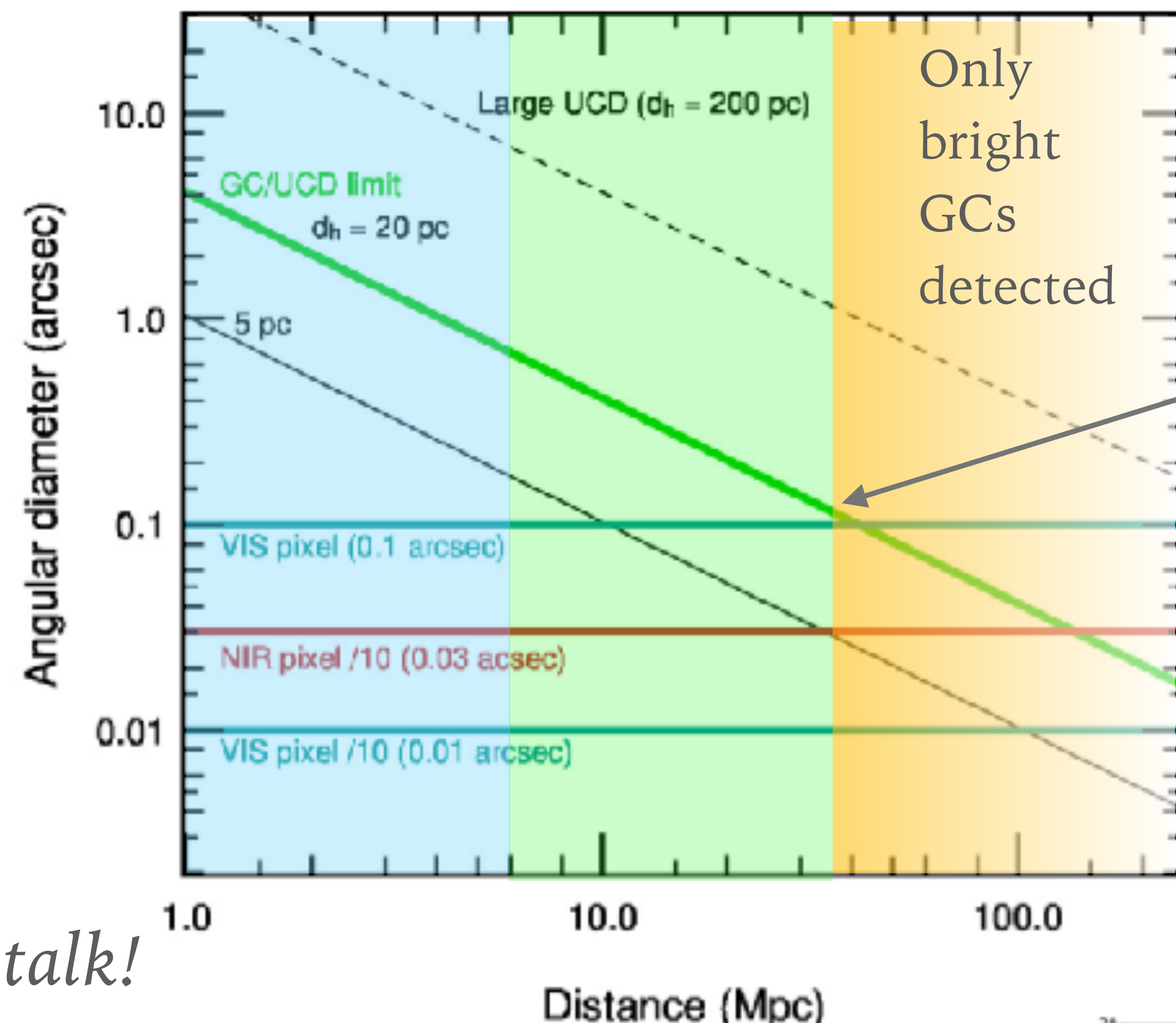

5 sigma detection at peak Mv=-8 of GCLF

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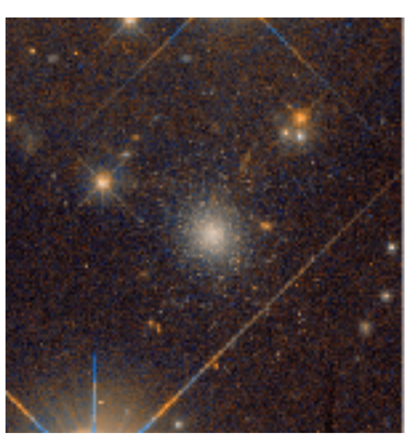

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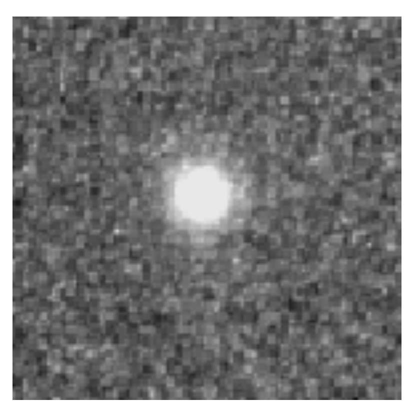

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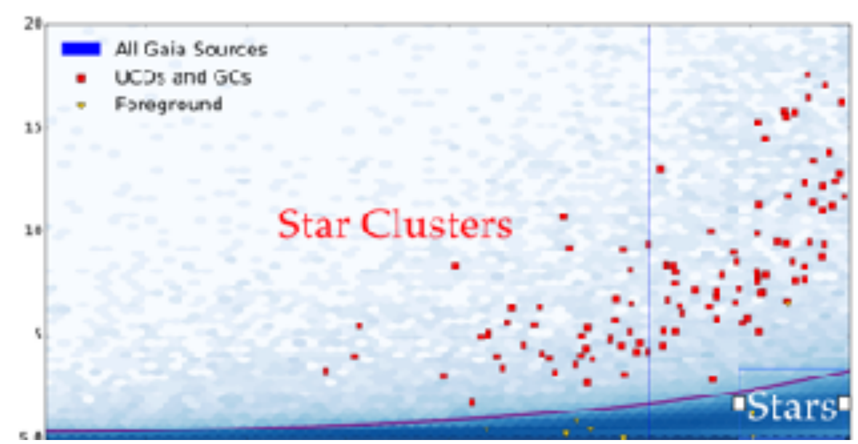


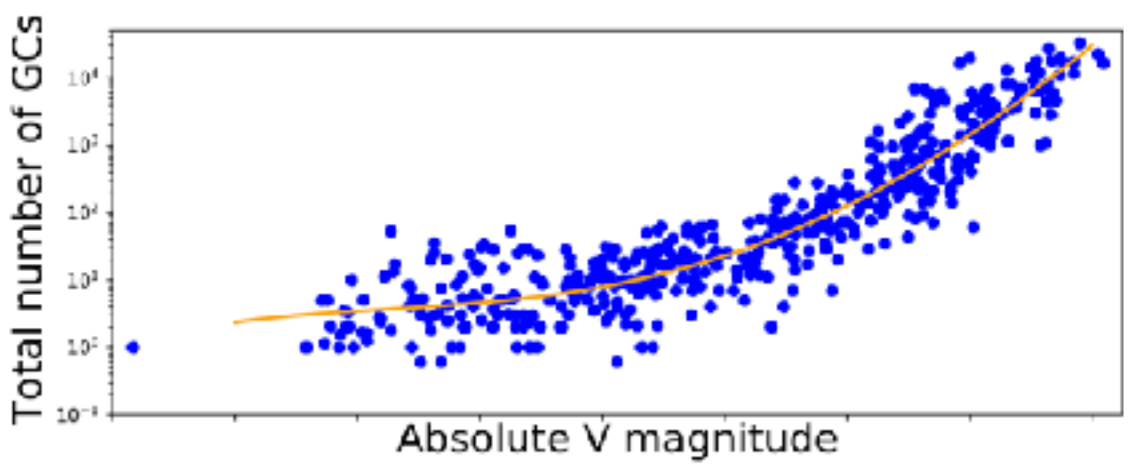
3.) Excess compared to PSF

THEORETICAL NUMBER OF GCS

LUNE galaxy catalogue (Crescenzo Tortora) has ~4000galaxies with magnitudes and distances <100Mpc in footprint

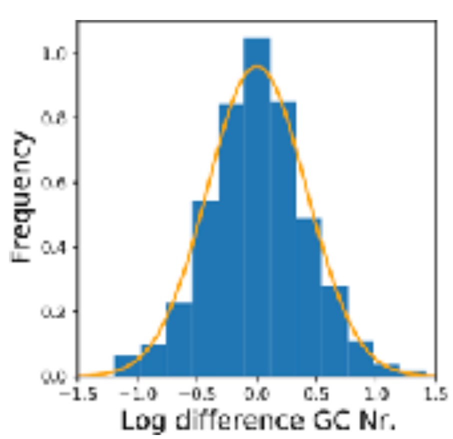
+

Average Nr of GCs for galaxy luminosity



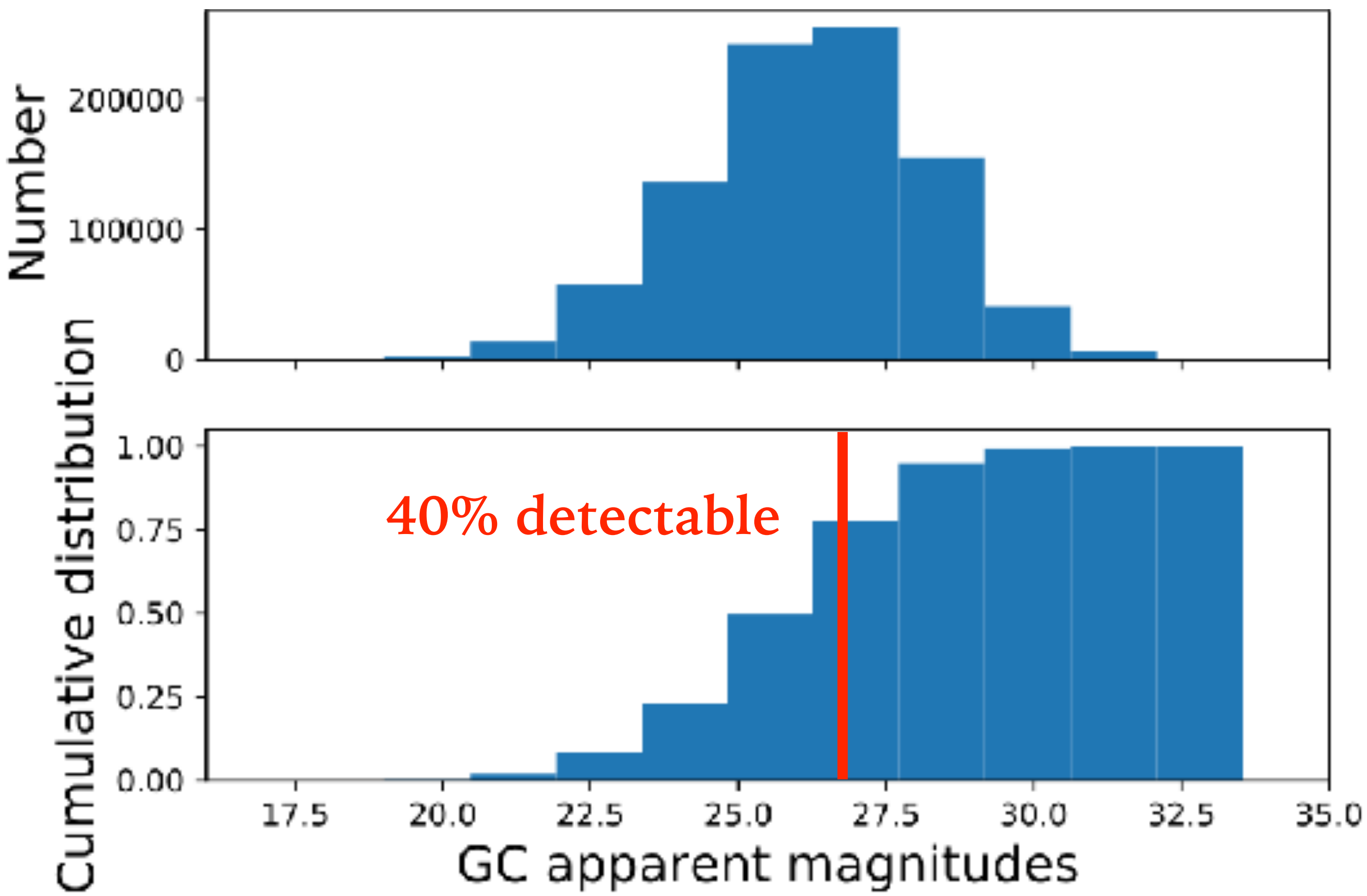
= Total Nr of predicted GCs for each galaxy in the LUNE catalogue.

+



Taking into account the GC Number scatter

THEORETICAL NUMBER OF GCS



- Drawing for **each** galaxy the magnitude of every GC from a typical Gaussian GC luminosity function (Mv=-7.5)
- Putting absolute GC magnitude to their correct apparent magnitude
- **-> distribution of all theoretical GC magnitudes in all footprint galaxies**

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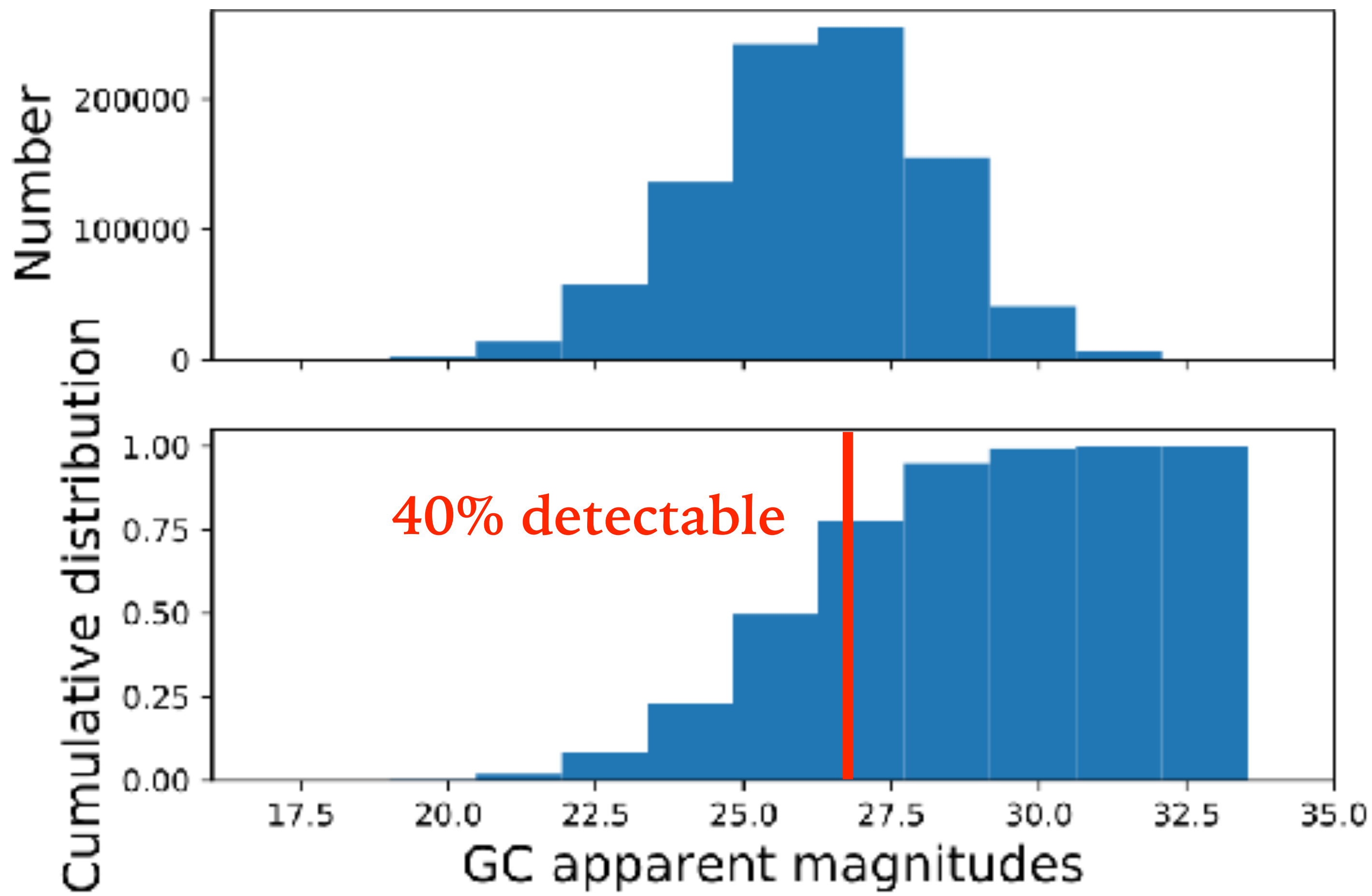
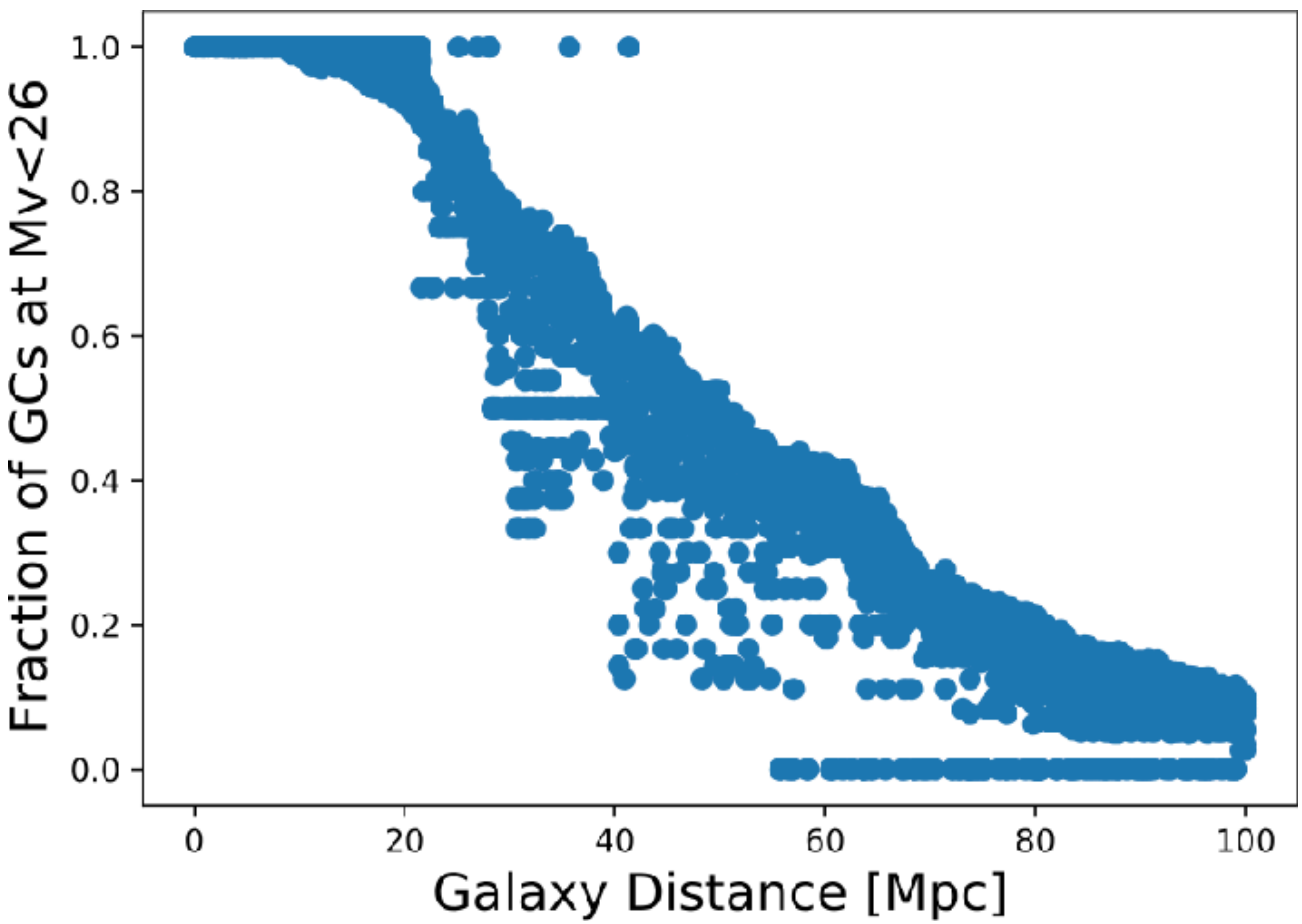
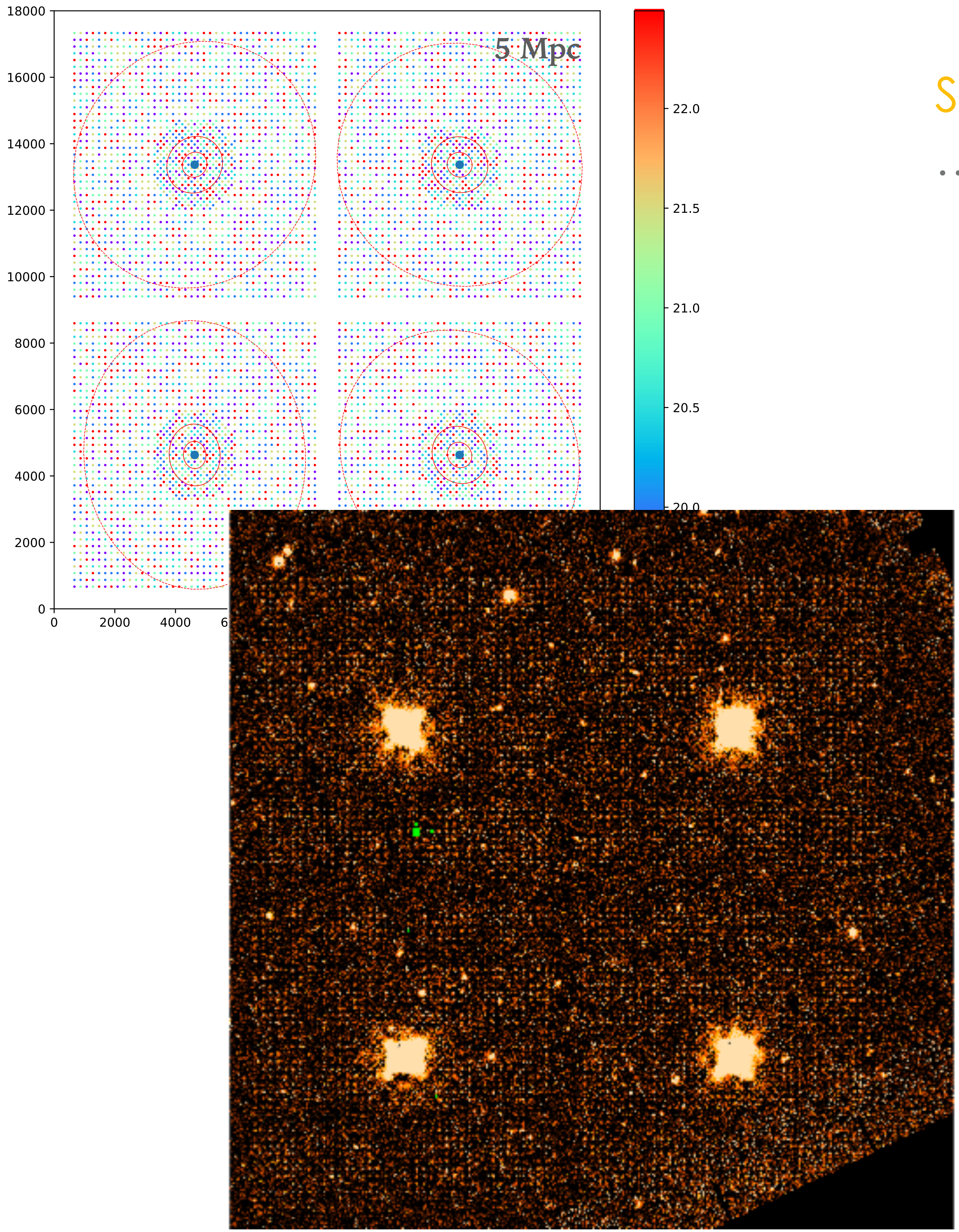


- Drawing for **each** galaxy the magnitude of every GC from a typical Gaussian GC luminosity function (Mv=-7.5)
- Putting absolute GC magnitude to their correct apparent magnitude
- **-> distribution of all theoretical GC magnitudes in all footprint galaxies**
- ~1 Million GCs in local galaxies in footprint
- **Of these ~400.000 or around 40% are brighter than mv=26.0 and thus in theory detectable**
- 235 000 are brighter than mv=25 and thus 25% -> bright enough to get Y, J, H photometry for these

DETECTABILITY AS A FUNCTION OF DISTANCE



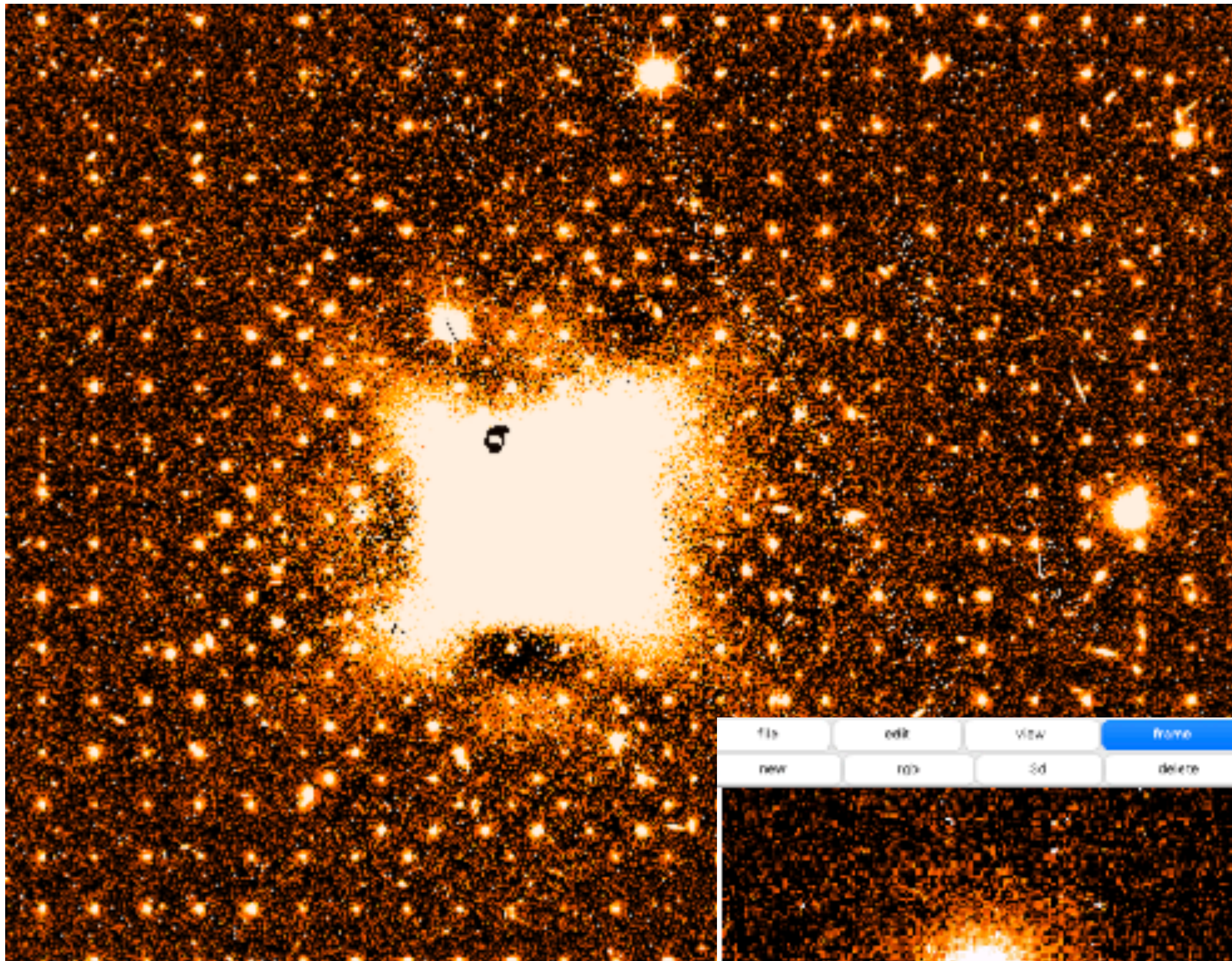
Based on LUNE galaxies & theoretical GC numbers, 50% of all GCs detectable at 50Mpc

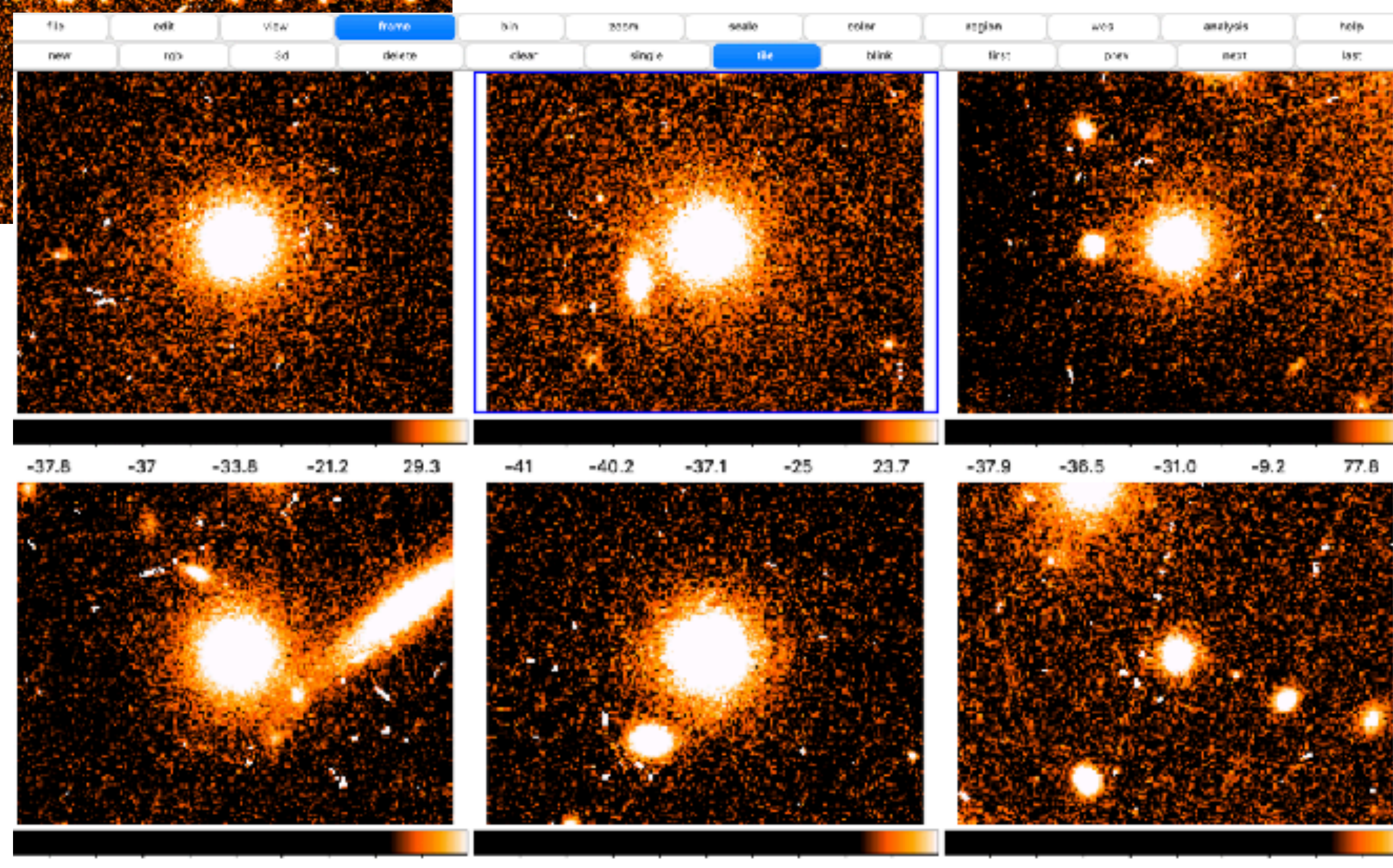


SIMULATIONS OF GCS IN EUCLID

- Simulations from OU-SIM of VIS tile (P. Hudelot, E. Jullo)
- After OU-VIS we get one OU-MER tile per distance
- Testing GC detectability as function of distance, magnitude, color and separation to host galaxy

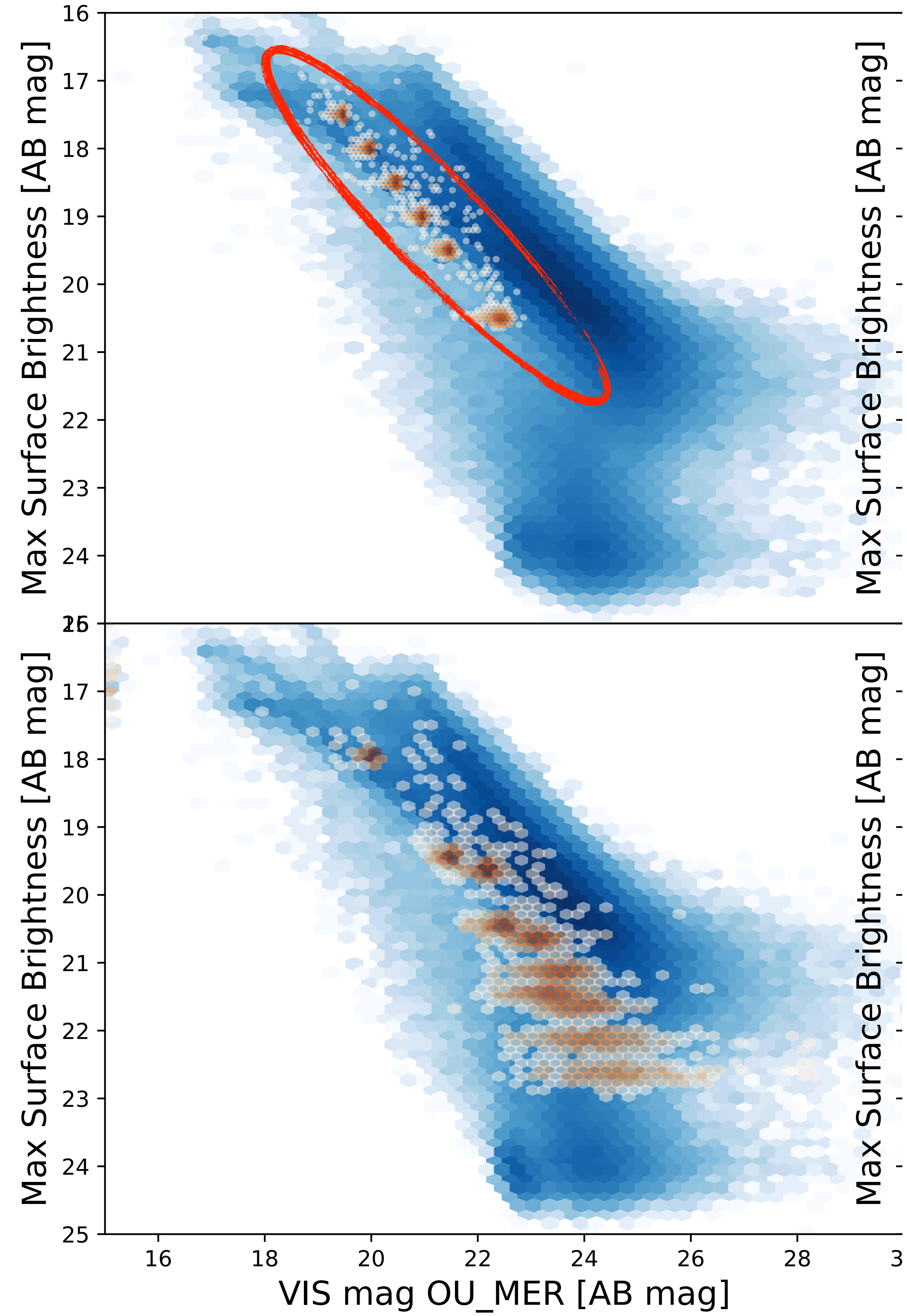
SIMULATIONS OF GCS IN EUCLID





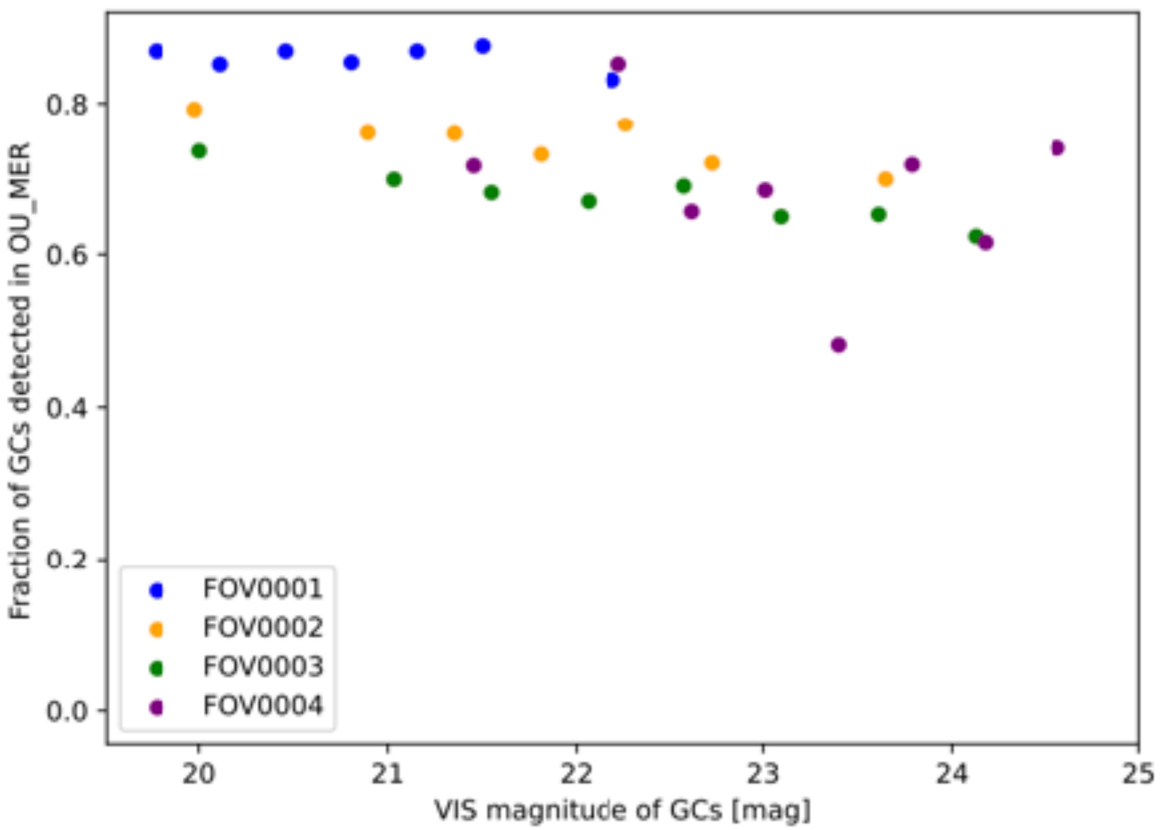
CANDIDATE GC SELECTION

1. Based on OU-MER output catalogue criteria that are sensitive to size and compactness (quick but less accurate)
2. Based on our own re-analysis of Euclid images (time consuming but more accurate)

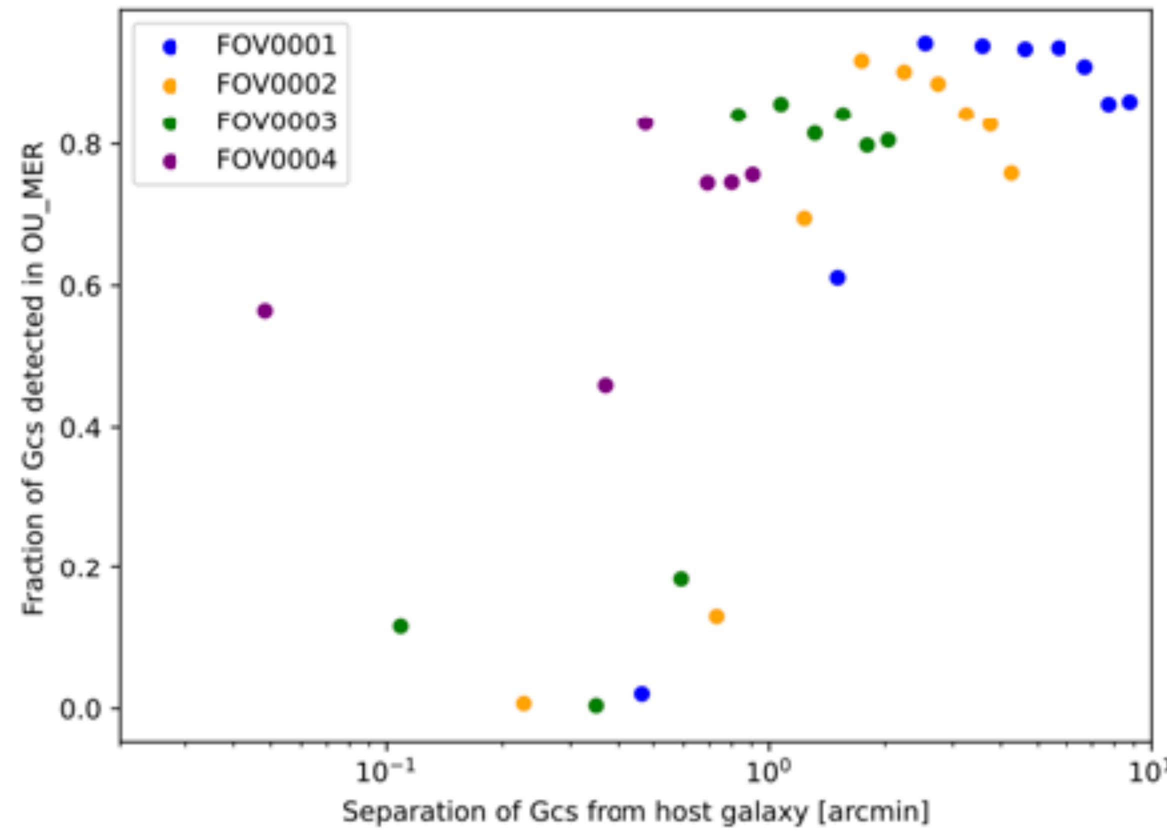


Both will be prepared but the second option needs a lot of computing power and e.g. very accurate psf.

COMPARISON BETWEEN IN AND OUTPUT CATALOGUES



Recovering 70-80% of GCs that were put into the simulations

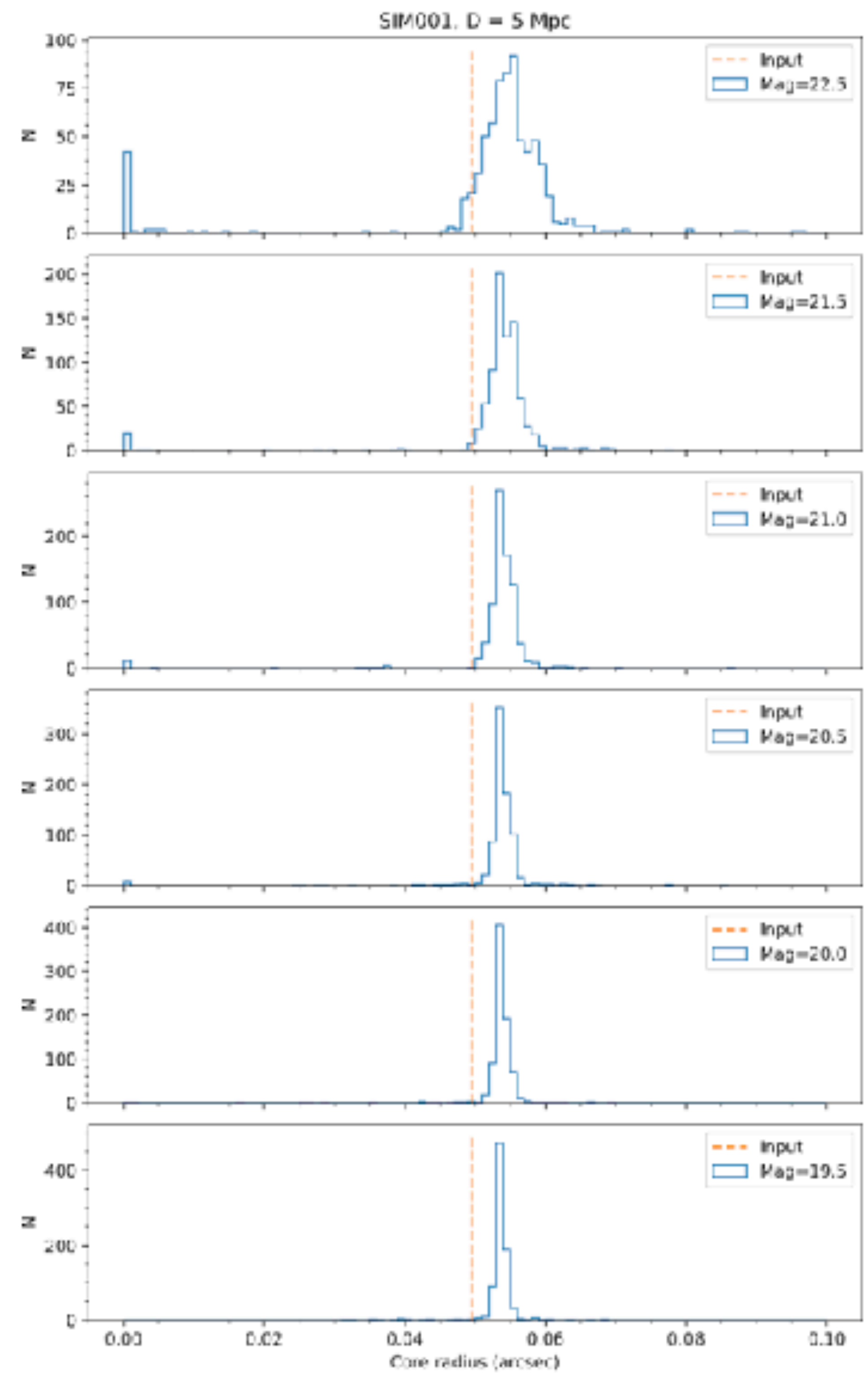


Recovering most GCs outside 1arcmin of the galaxy center

HOW FAR OUT CAN WE MEASURE STRUCTURAL PARAMETERS?

First example results from **Søren Larsen** with Ishape on the sizes of recovered from the simulated images with artificial Globular Clusters

- Radii slightly too large but able to measuring GCs as extended sources until out to 20Mpc at least
- Limiting: having the accurate PSF for every field



EXTRAGALACTIC GCS WITH EUCLID

- Detectability paper is in preparation and advancing
- **We expect ~400.000 detectable GCs in Euclid imaging from theoretical predictions**
- We have set of simulation of VIS imaging with artificial GCs on which we base our analysis
  - Purity and completeness estimates
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Future:

- Prepare catalogues of known GCs as training samples from first year science.
- Machine learning pipelines that automate candidate selection
- Plan systematic spectroscopic follow-up of the candidates to make them useful for dynamical studies