The star cluster formation history of the Large Magellanic Cloud

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Introduction

Image Credit: ESO/VLT

Introduction

The MC and the MW have been a triple system for at least 1 Gyr (Bekki&Chiba05)

SMC
60 Kpc

MW

LMC
50 Kpc

Image Credit: ESO/VLT

Introduction

The MC and the MW have been a triple system for at least 1 Gyr (Bekki&Chiba05)
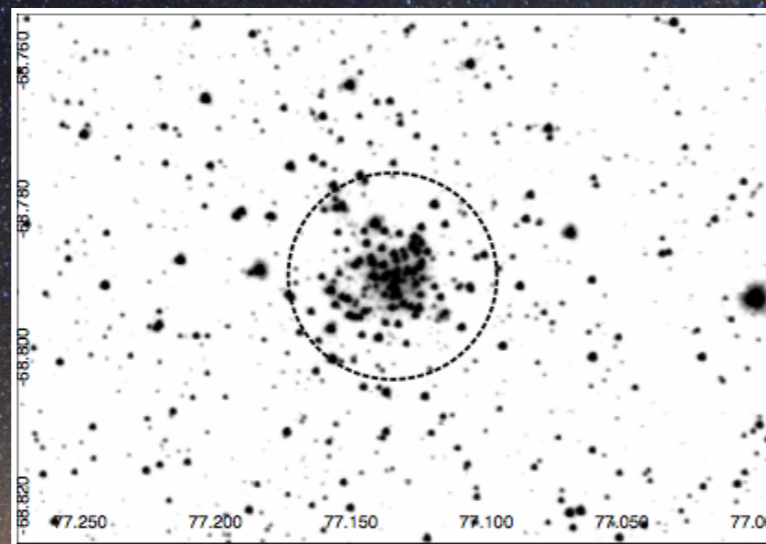
SMC
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Image Credit: ESO/VLT
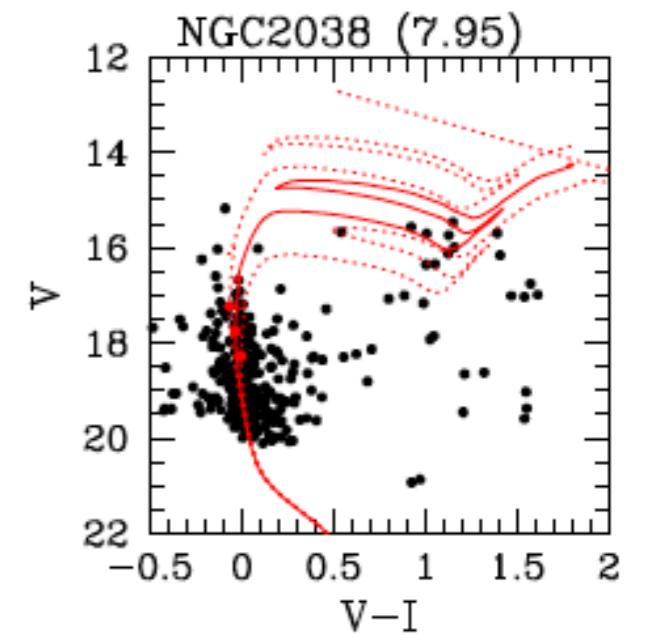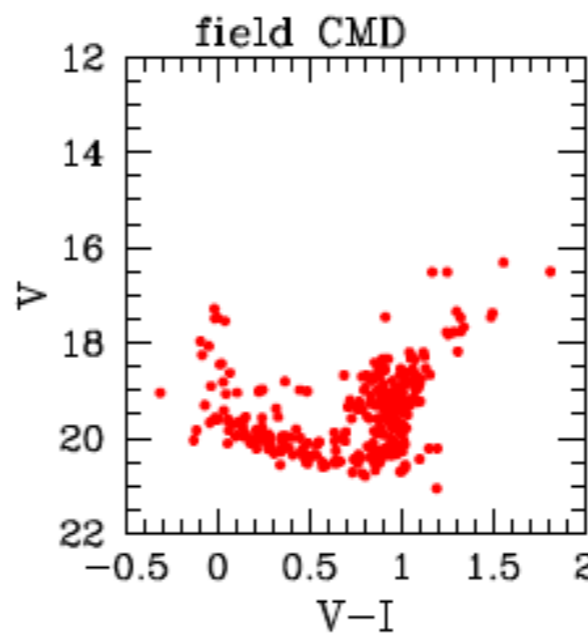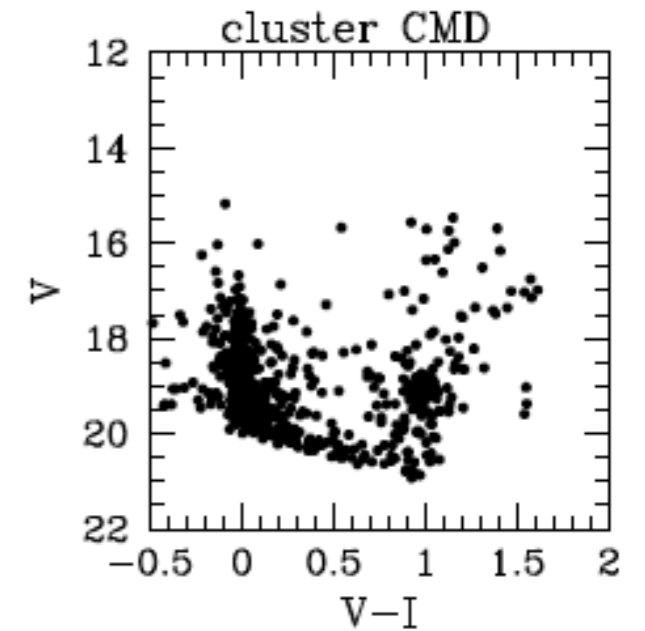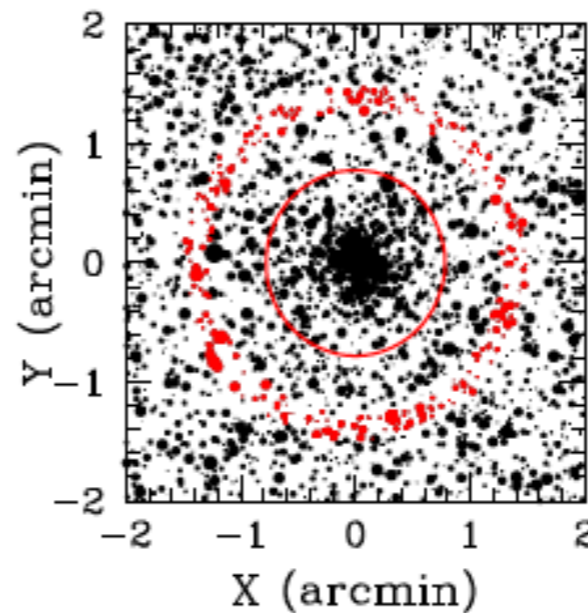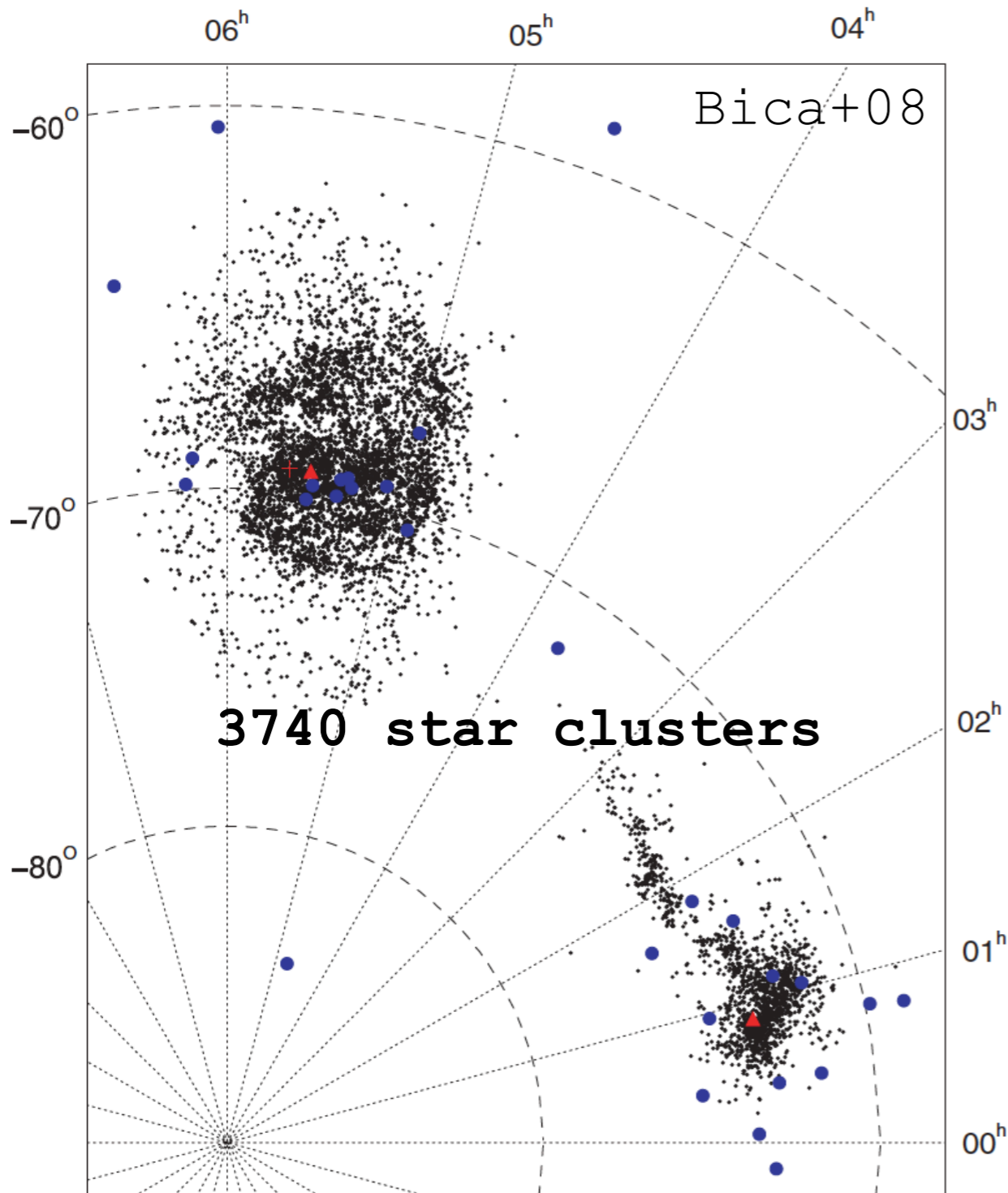
Cluster identification/age determination techniques

Bica+08

3740 star clusters

cluster CMD

field CMD

NGC2038 (7.95)

Nayak+16

Problems/biases

- All existing LMC cluster samples are **not complete/uniform**

- The **detection methods vary** with most of them being identified by **visual** means

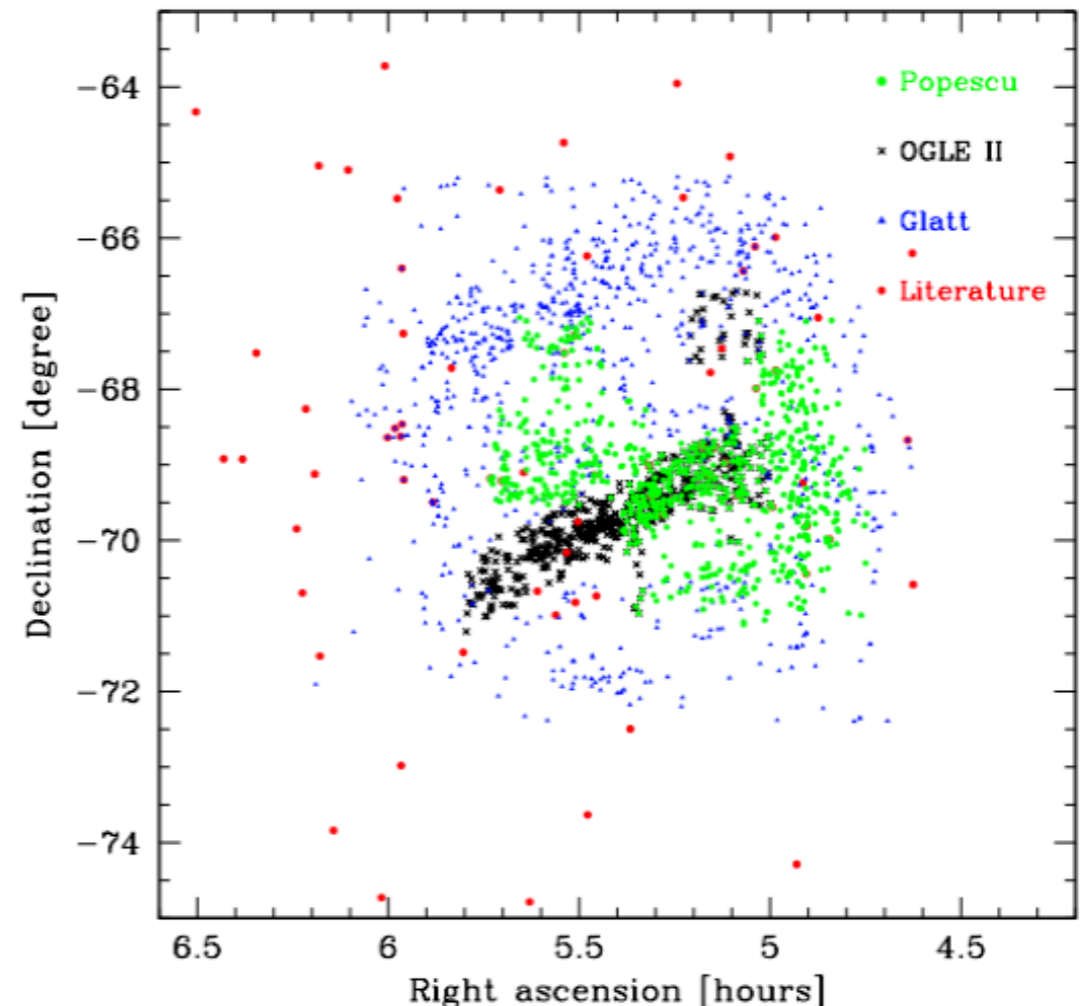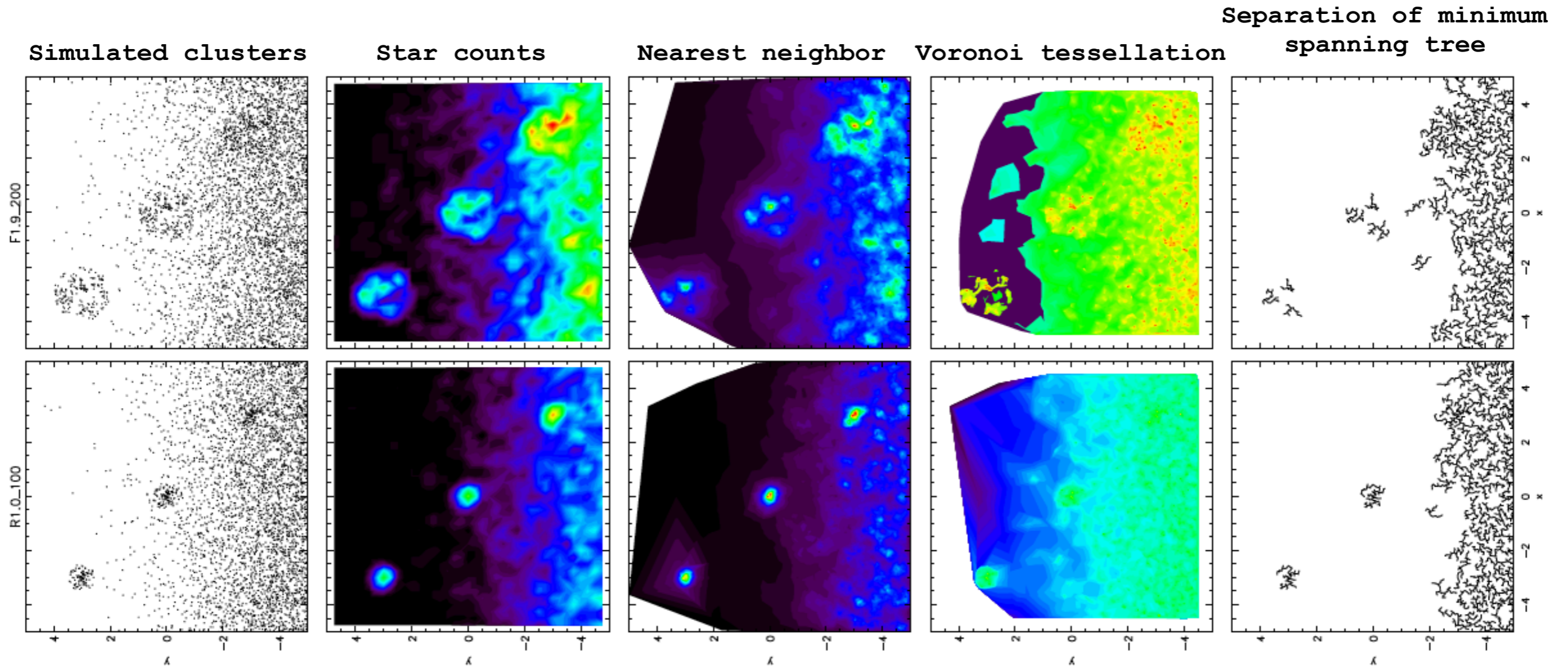- The **age determination** is done also by mostly **visual** means
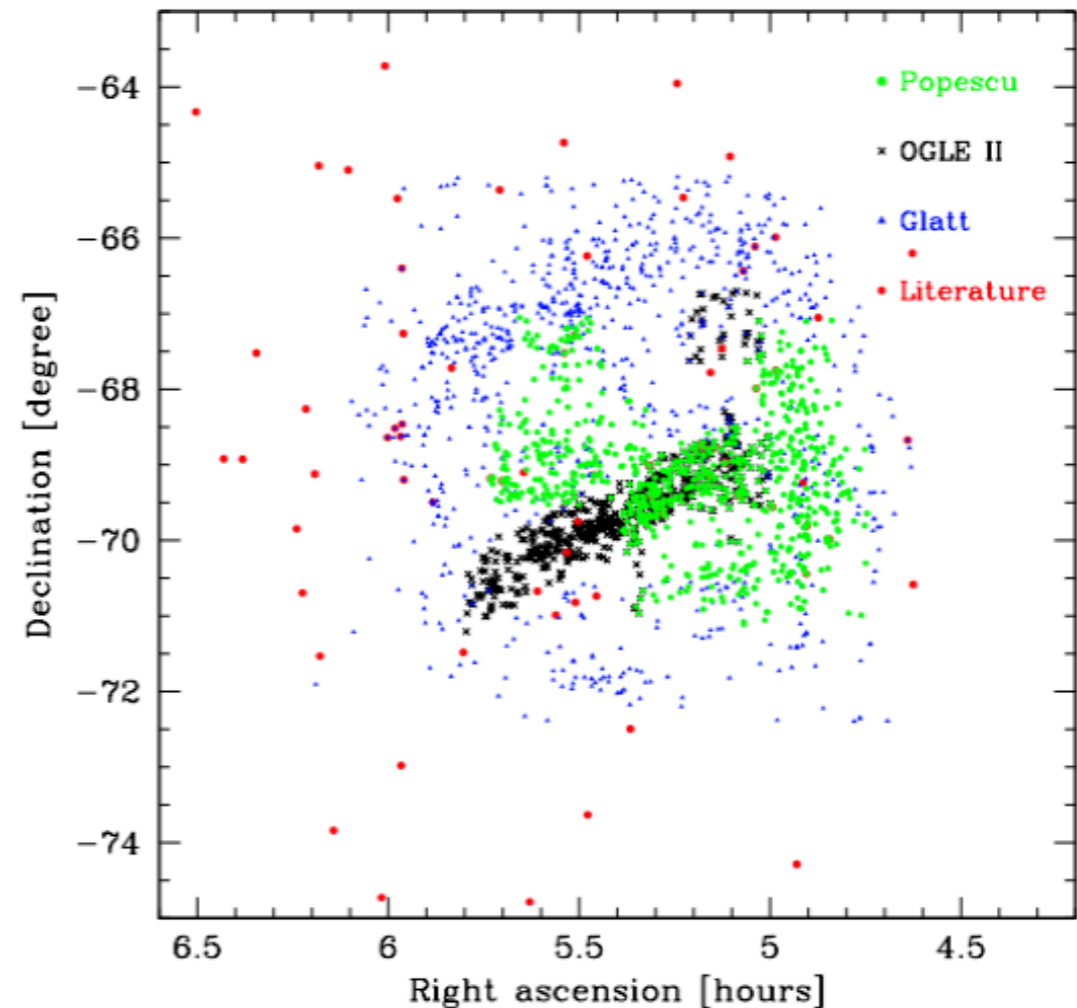
Problems/biases

- All existing LMC cluster samples are **not complete/uniform**

- The **detection methods vary** with most of them being identified by **visual** means

- The **age determination** is done also by mostly **visual** means

- Use a **automated method** to detect and create **uniform samples** of star clusters

- Estimate ages using a **statistically robust method**

- Study the **star cluster formation history** as well as the **luminosity functions** and **IMF** of the clusters
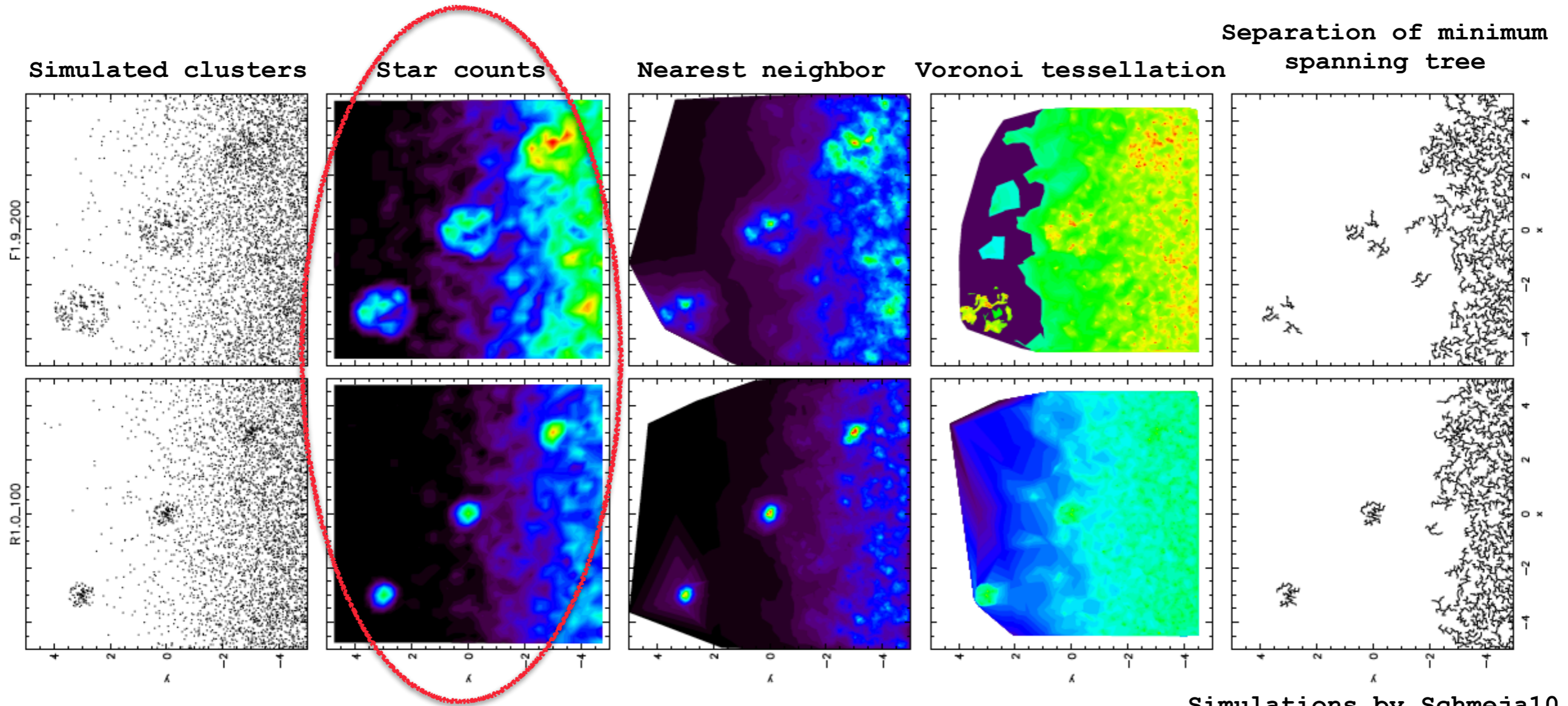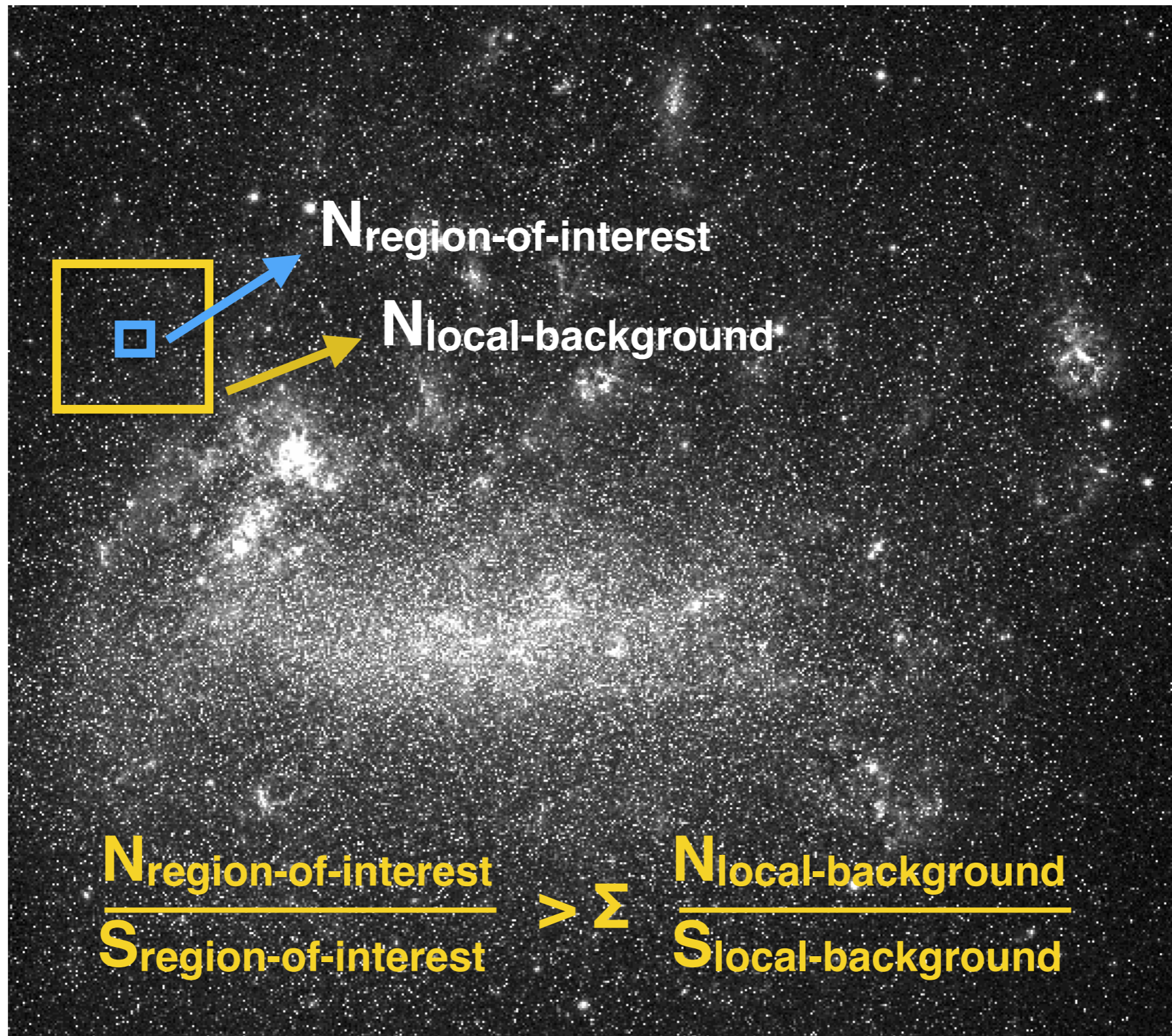
Detection methods

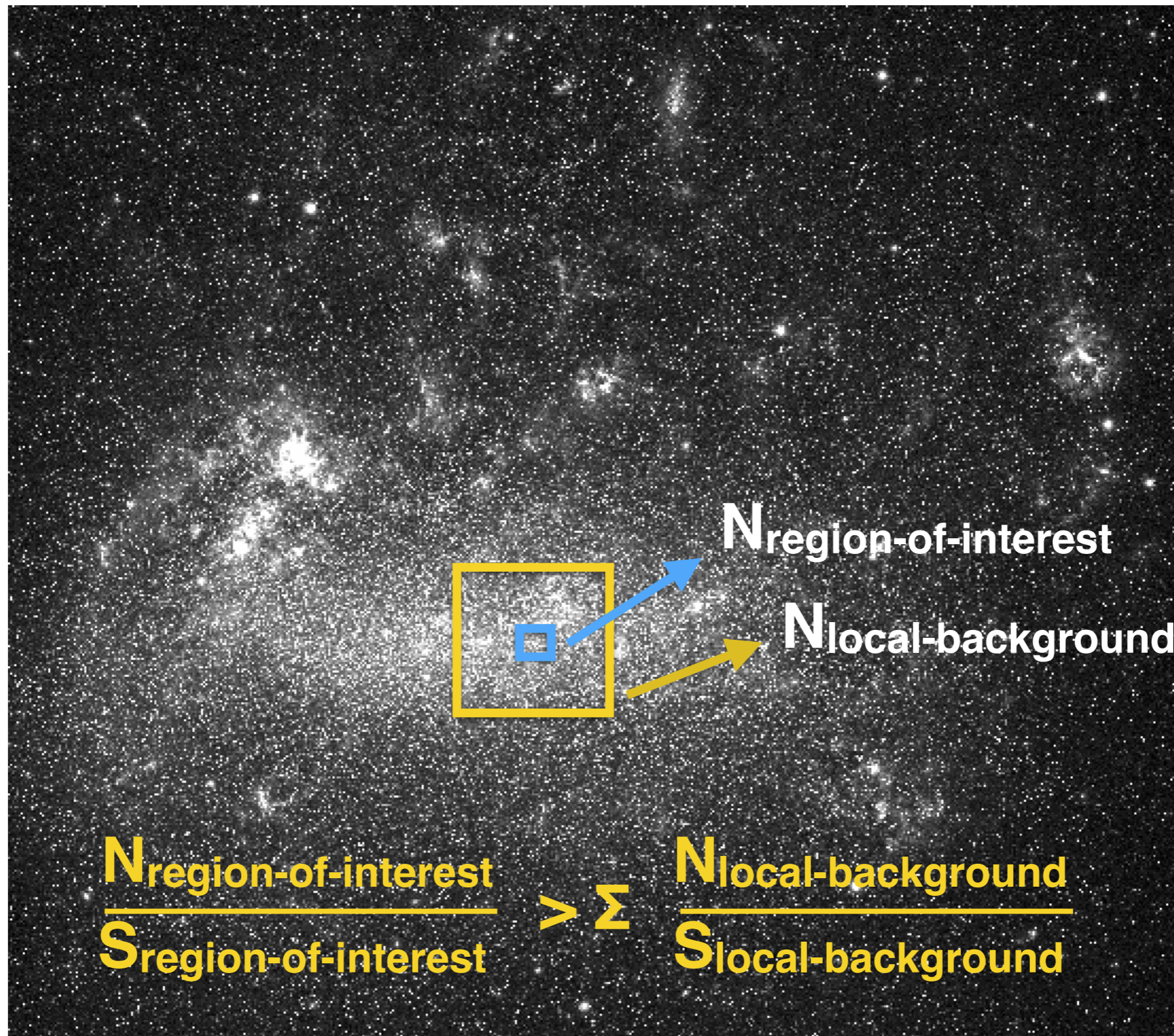Simulated clusters   Star counts   Nearest neighbor   Voronoi tessellation   Separation of minimum spanning tree

Simulations by Schmeja10

Detection methods

Simulated clusters Star counts Nearest neighbor Voronoi tessellation Separation of minimum spanning tree

Simulations by Schmeja10

Identification method

$N_{\text{region-of-interest}}$

$N_{\text{local-background}}$

$$\frac{N_{\text{region-of-interest}}}{S_{\text{region-of-interest}}} > \Sigma \frac{N_{\text{local-background}}}{S_{\text{local-background}}}$$

Identification method

$N_{region\text{-}of\text{-}interest}$

$N_{local\text{-}background}$

$$\frac{N_{region\text{-}of\text{-}interest}}{S_{region\text{-}of\text{-}interest}} > \Sigma \frac{N_{local\text{-}background}}{S_{local\text{-}background}}$$

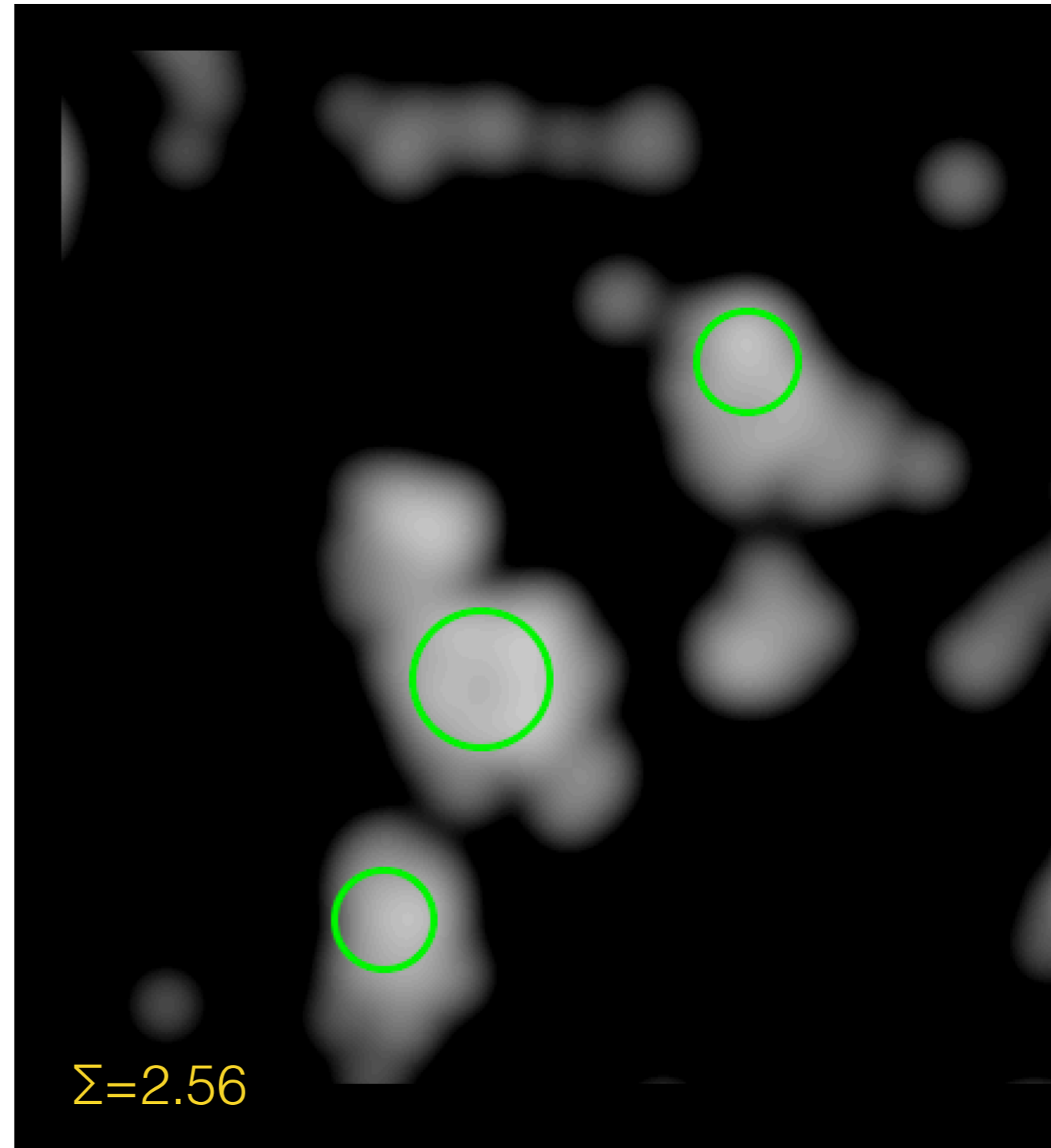# Cluster Simulations
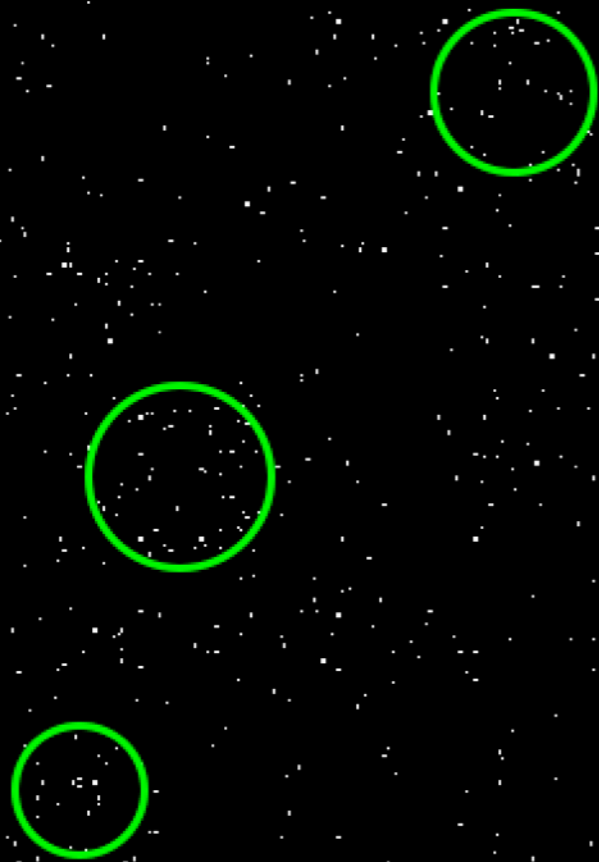
We use a variable Σ

Simulated Clusters.
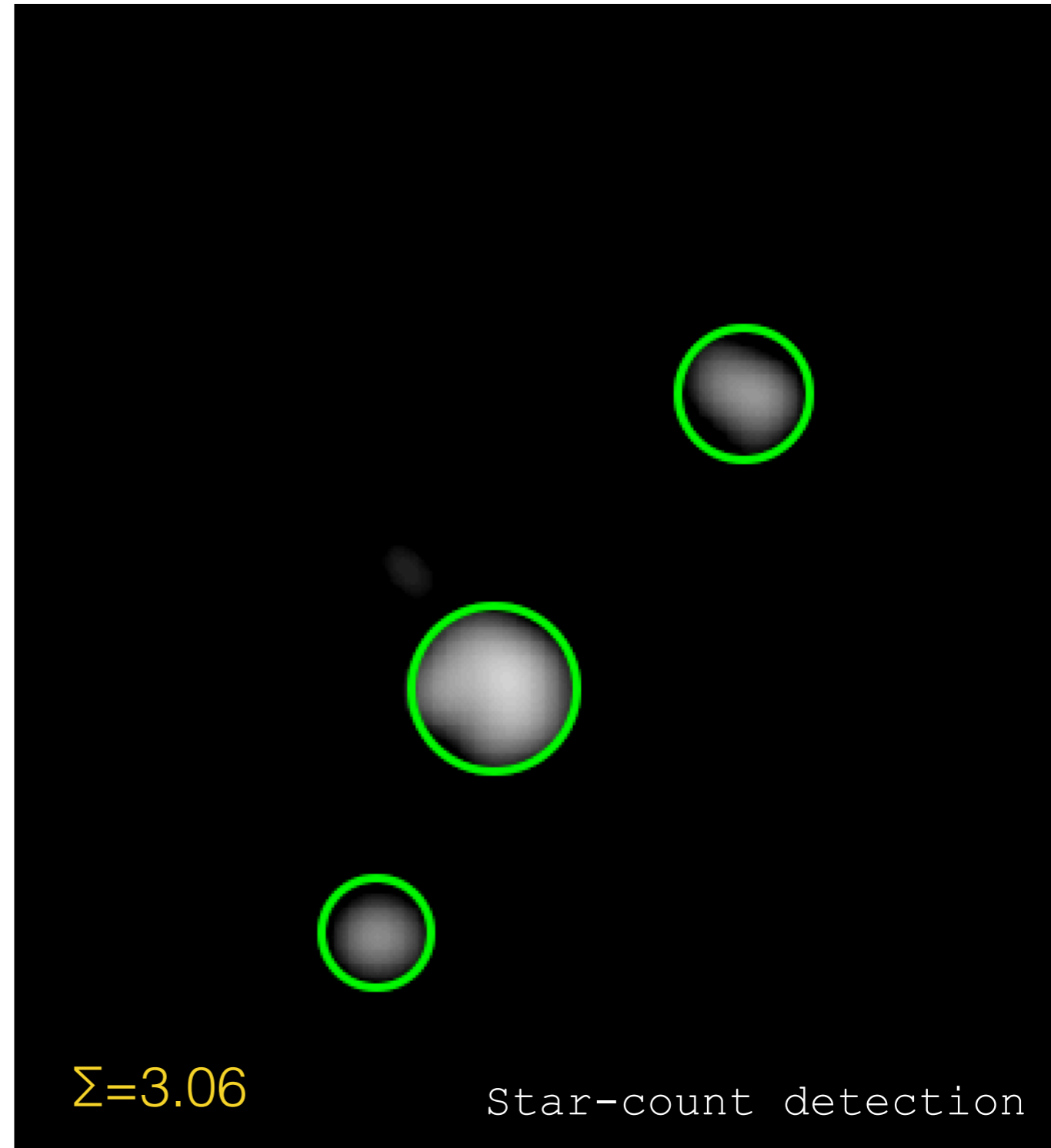
Σ=3.06

Star-count detection
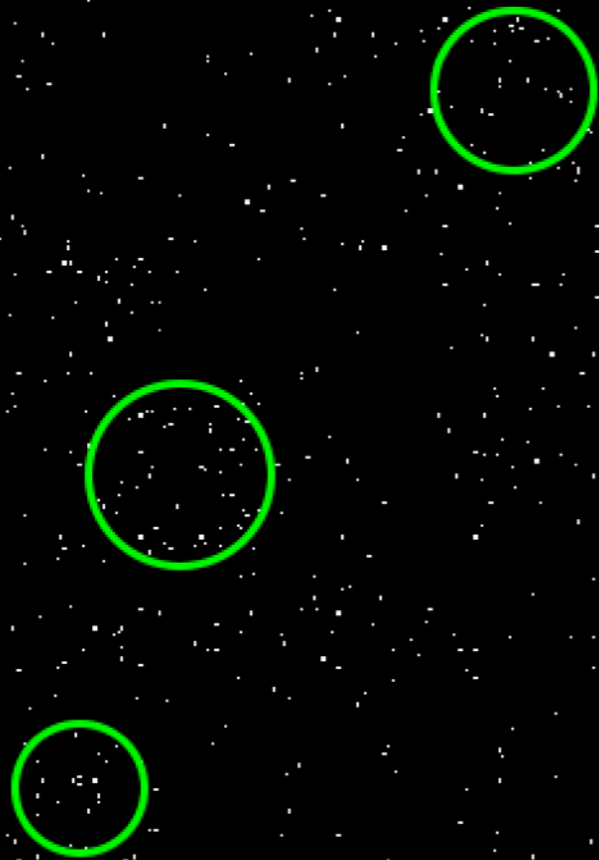
Cluster Simulations
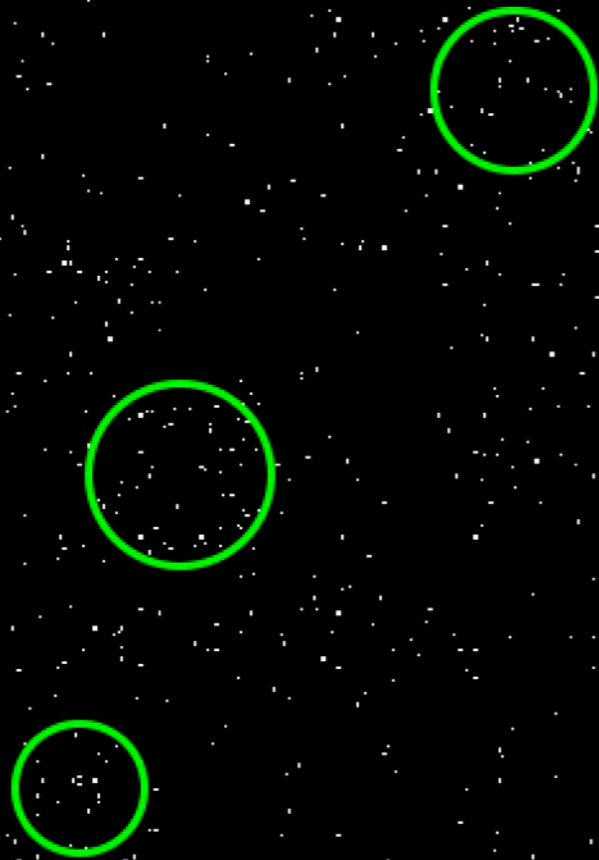
We use a variable Σ

Simulated Clusters.

Σ=2.56

Cluster Simulations

We use a variable Σ

Maximize cluster detections
Minimize detection of false associations

Simulated Clusters.

Σ=2.56

Sample

- We start from the **Large Magellanic Cloud**
- We use archival data from Simons+14, SUMAC, MCPS, MCELLS, SAGE, and Herschel Heritage
- Our sample comprises:
  - Ultraviolet: GALEX, SWIFT (coverage 7.5×7.5^o of LMC)
  - Optical: Las Campanas, CTIO-Hα
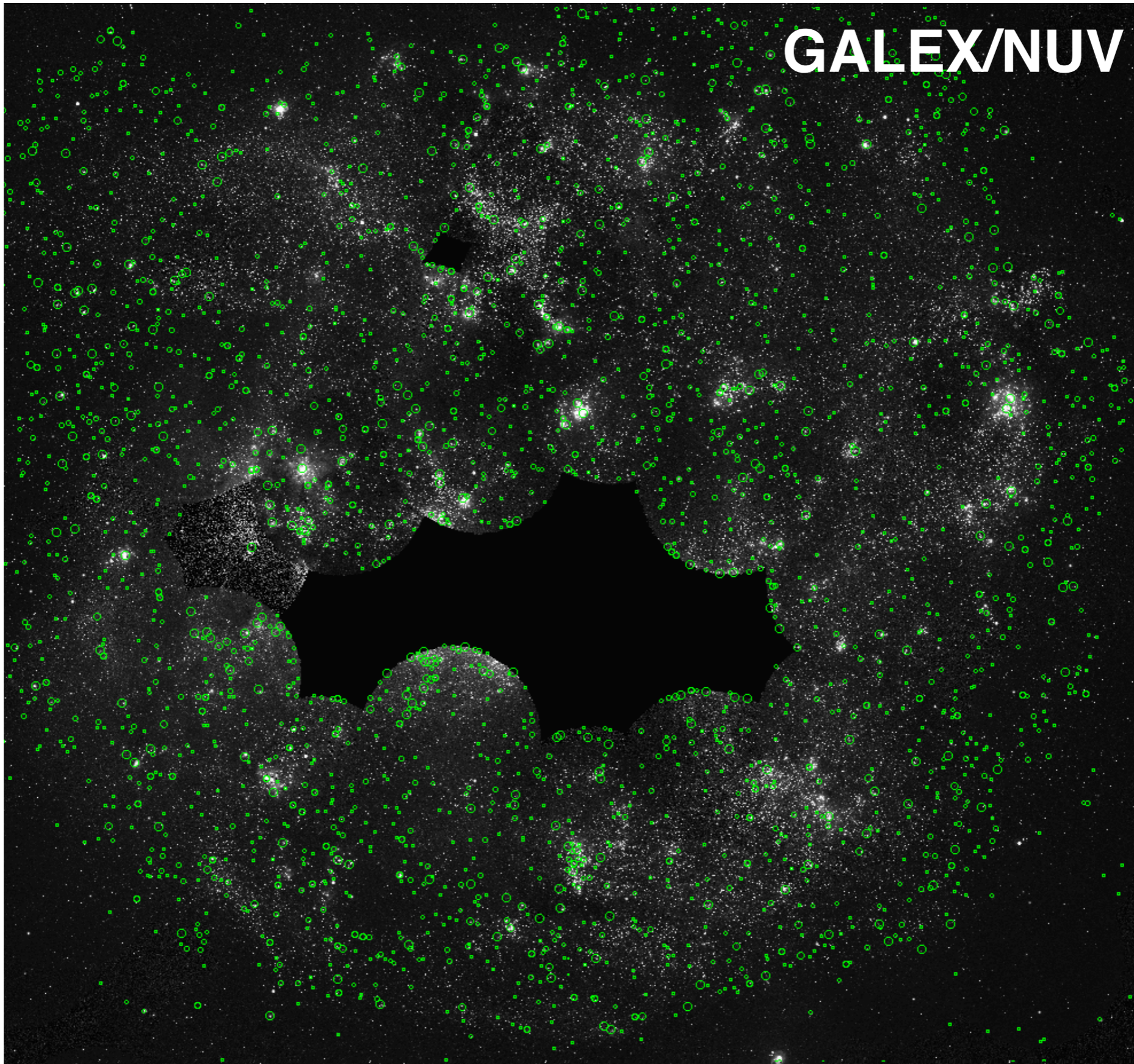 - Infrared: Spitzer, Herschel
  - Radio: CO(1-0), HI (mom-0 & velocity maps)

SWIFT
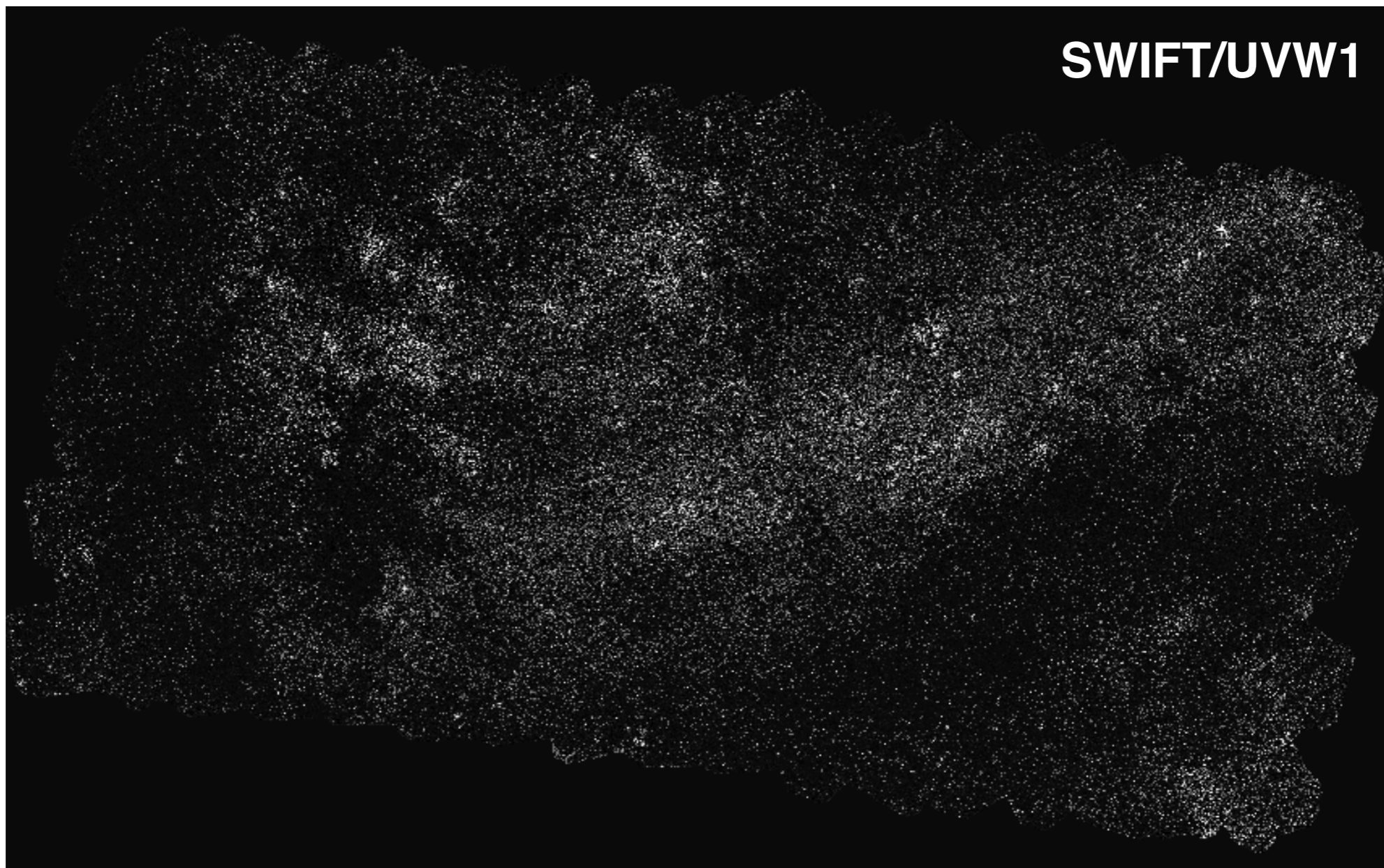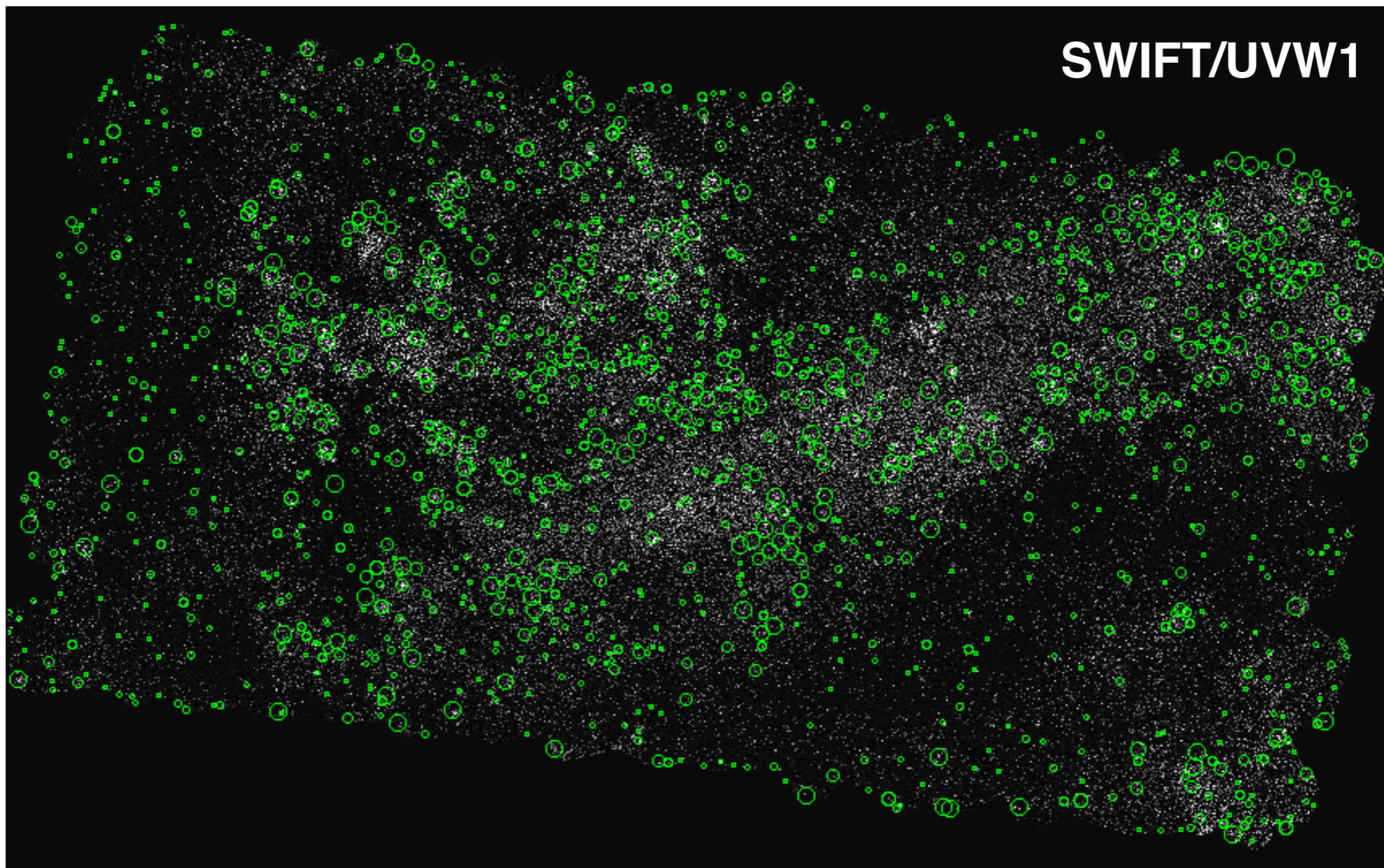
GALEX

SPITZER/IRAC

CTIO-Hα

SPITZER/MIPS
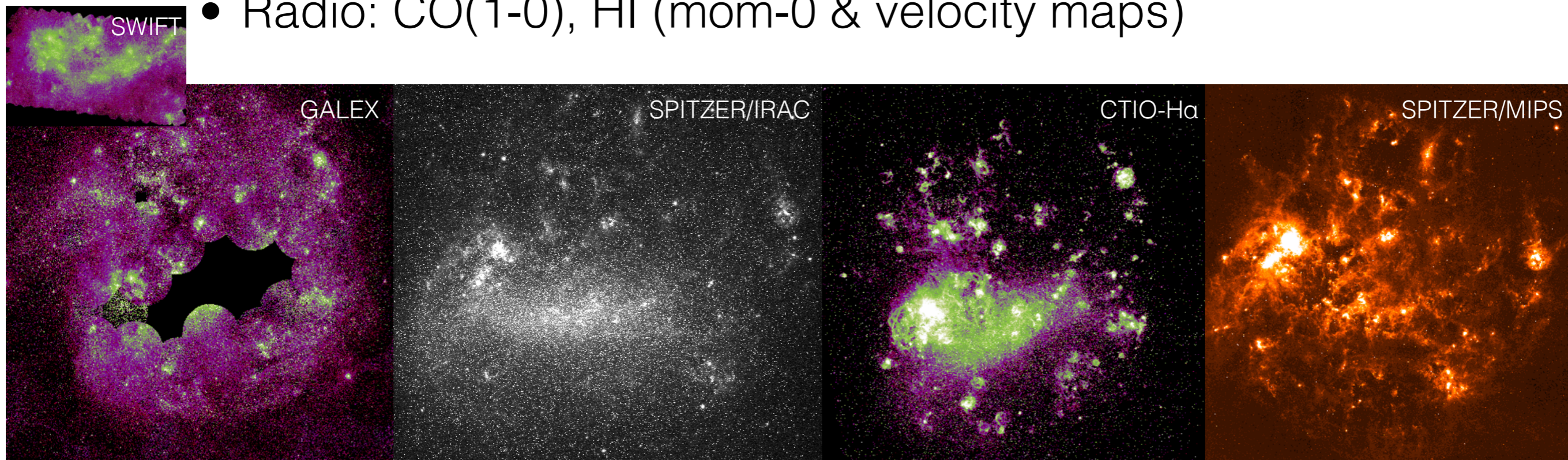
GALEX/NUV

GALEX/NUV

SWIFT/UVW1

SWIFT/UVW1
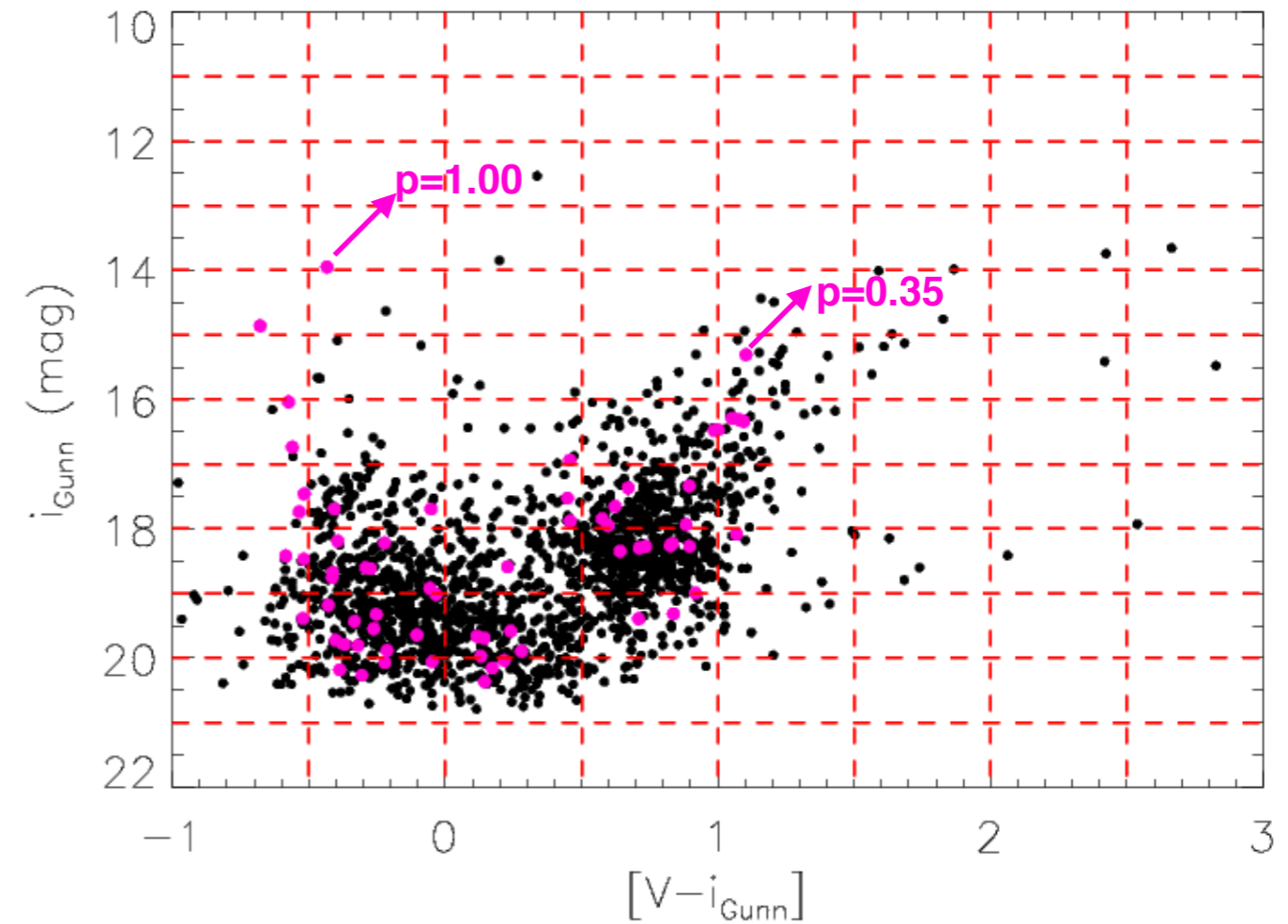
Spitzer/IRAC 3.6
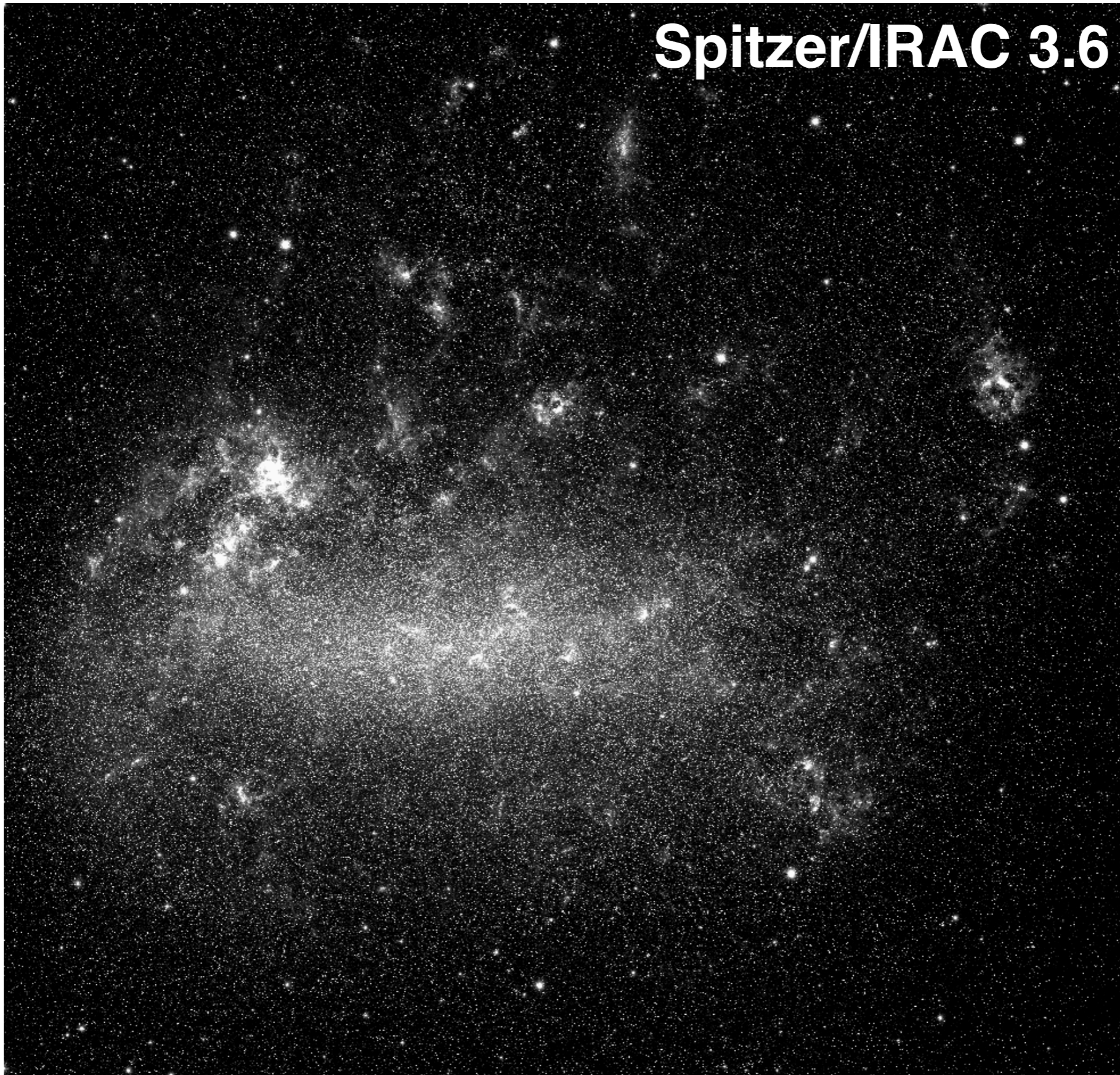
Spitzer/IRAC 3.6
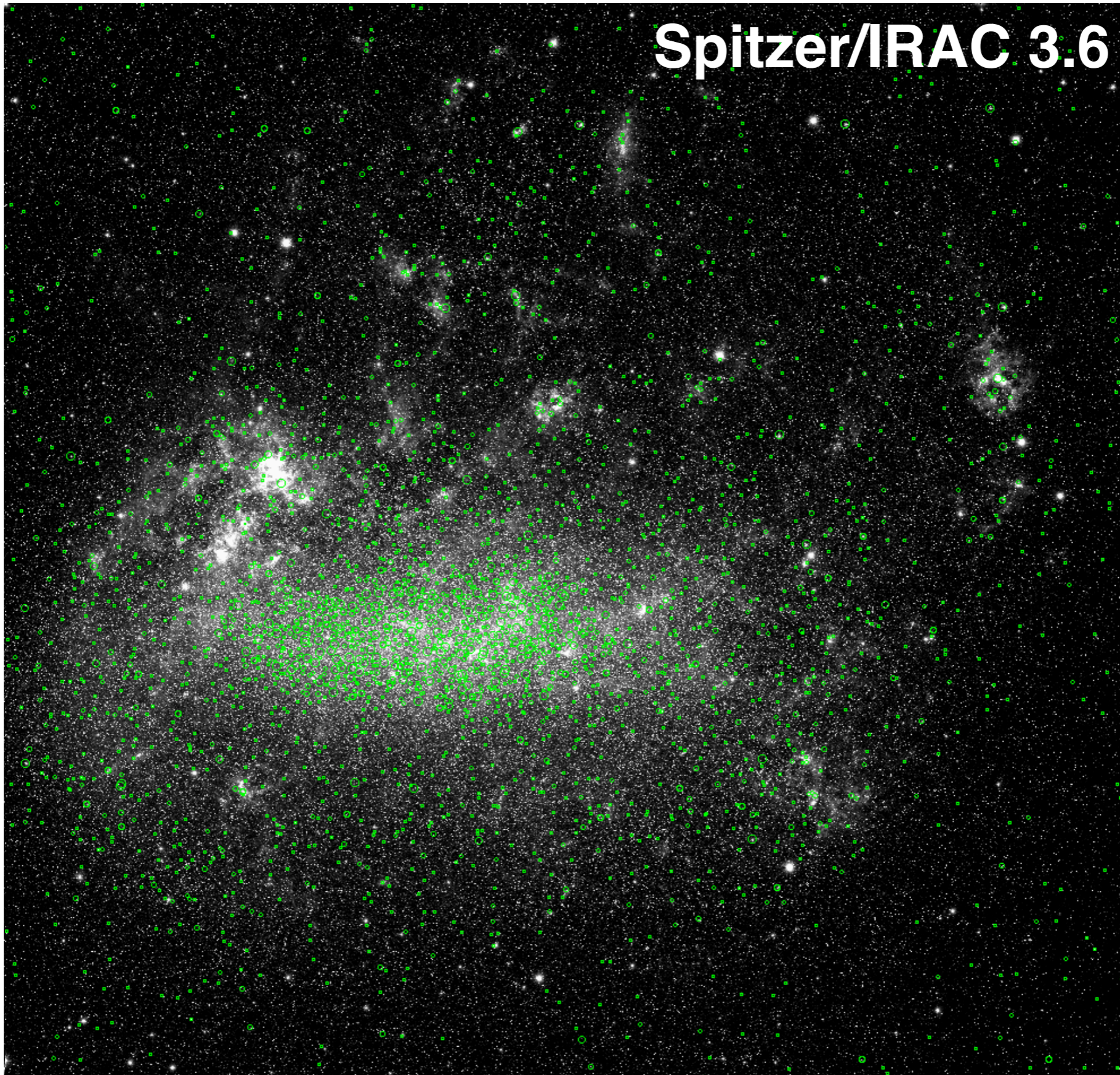
Spitzer/IRAC 3.6

In total we detected **5459** cluster candidates!
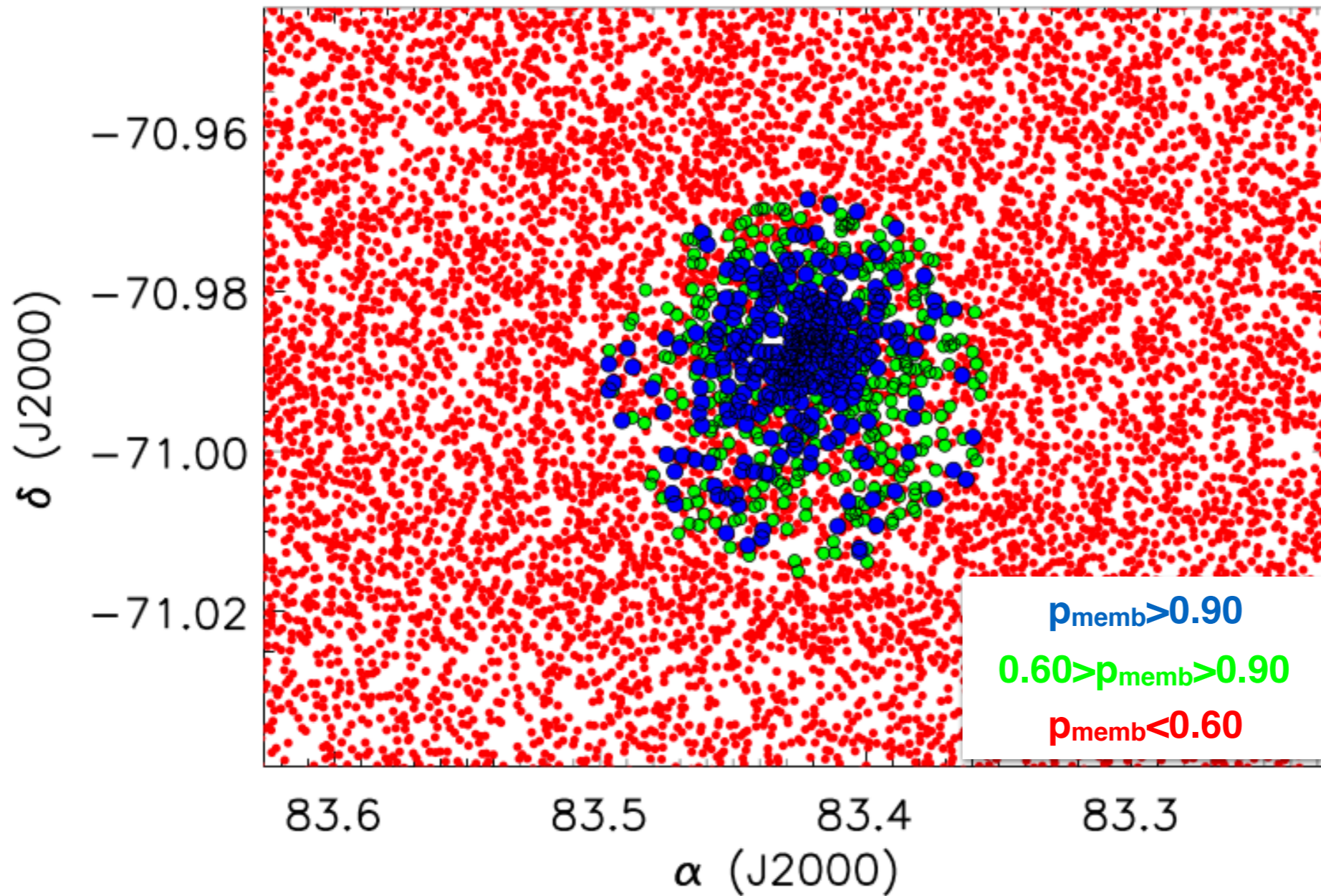
Field star contamination
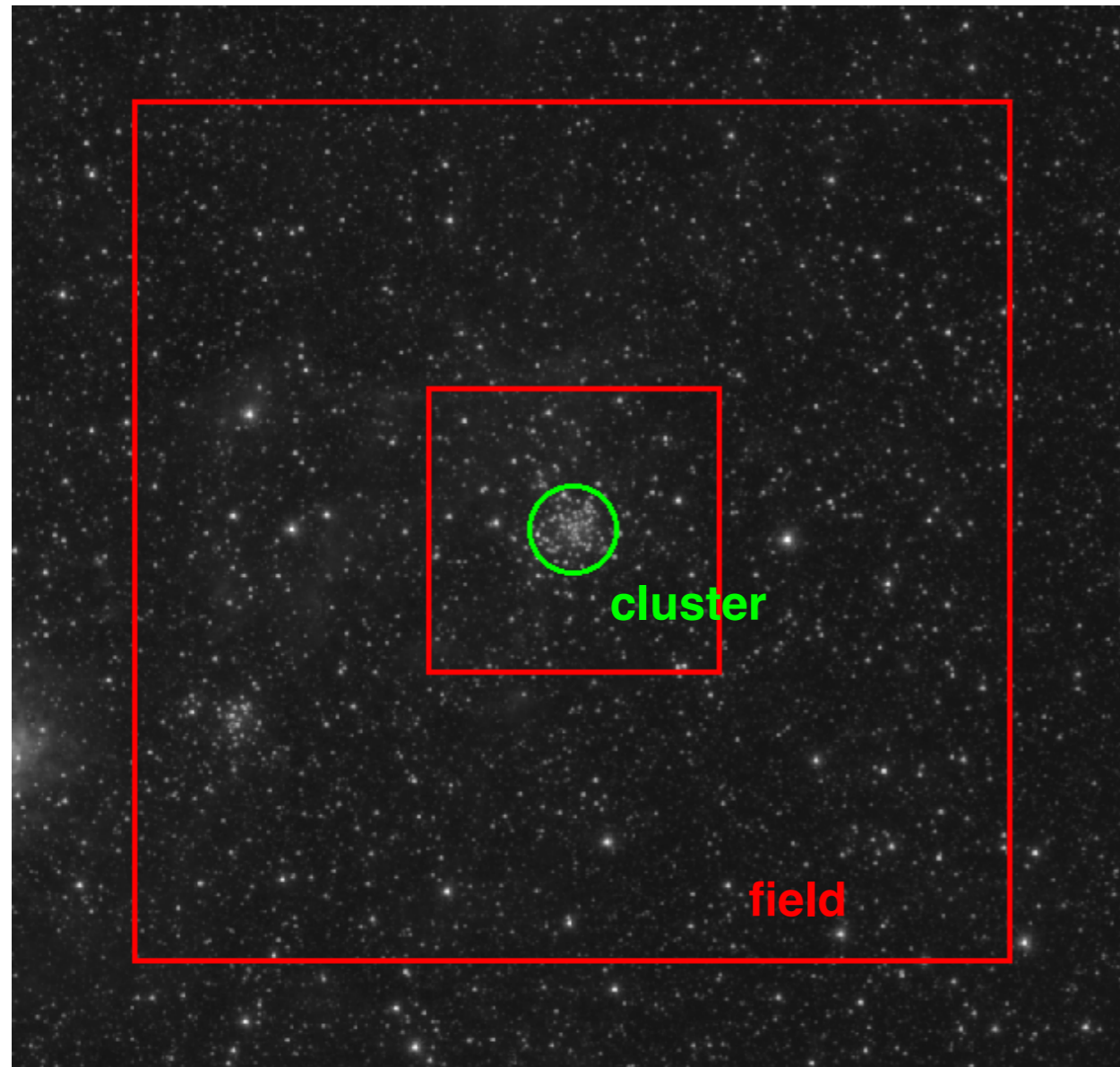
We use a modified version of the field star selection method described in Mighell+96
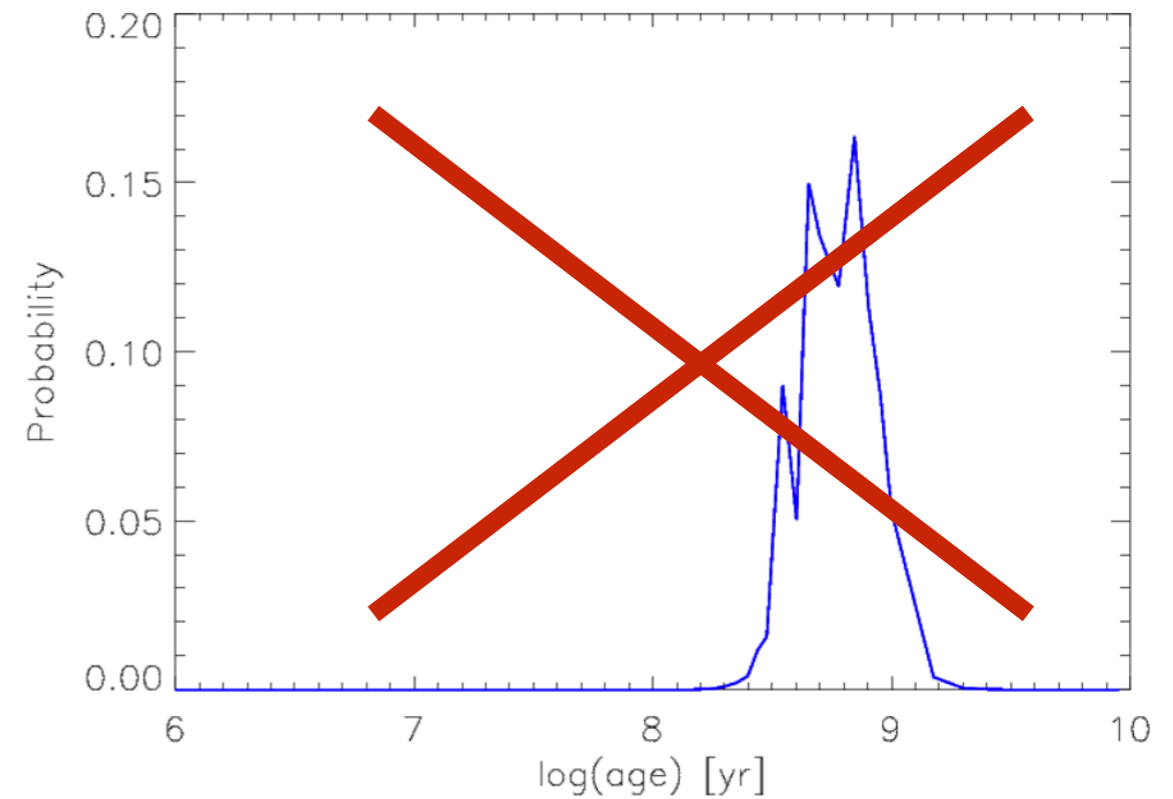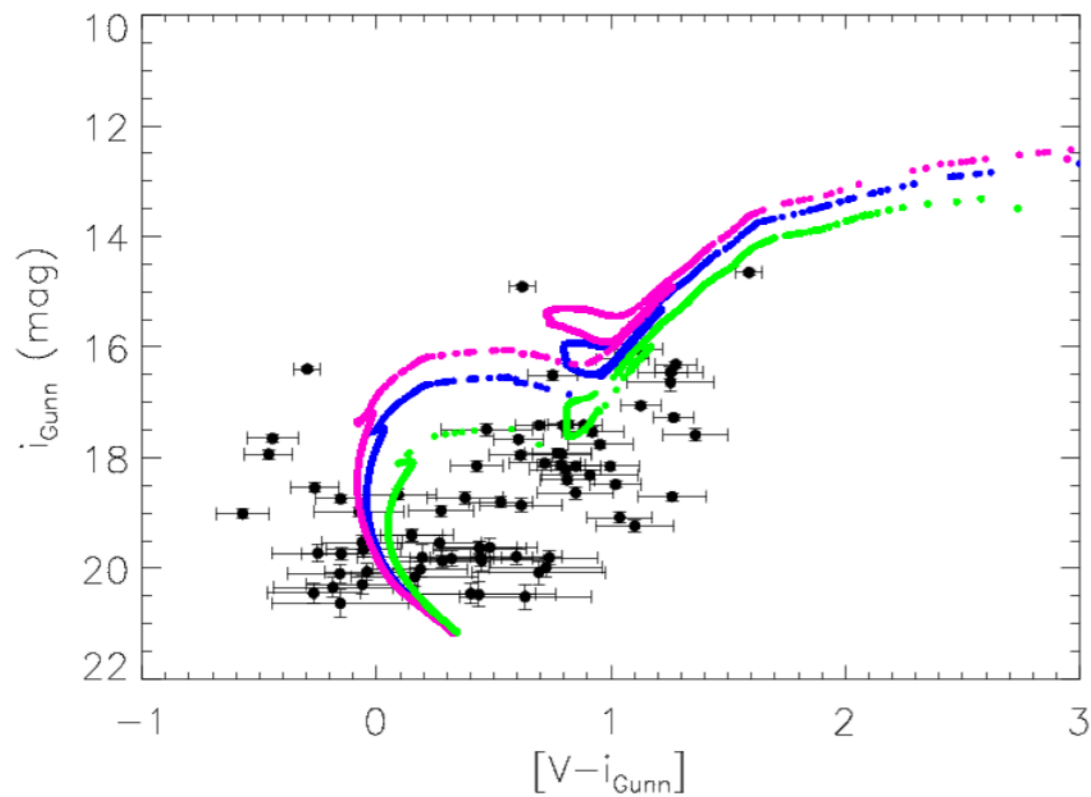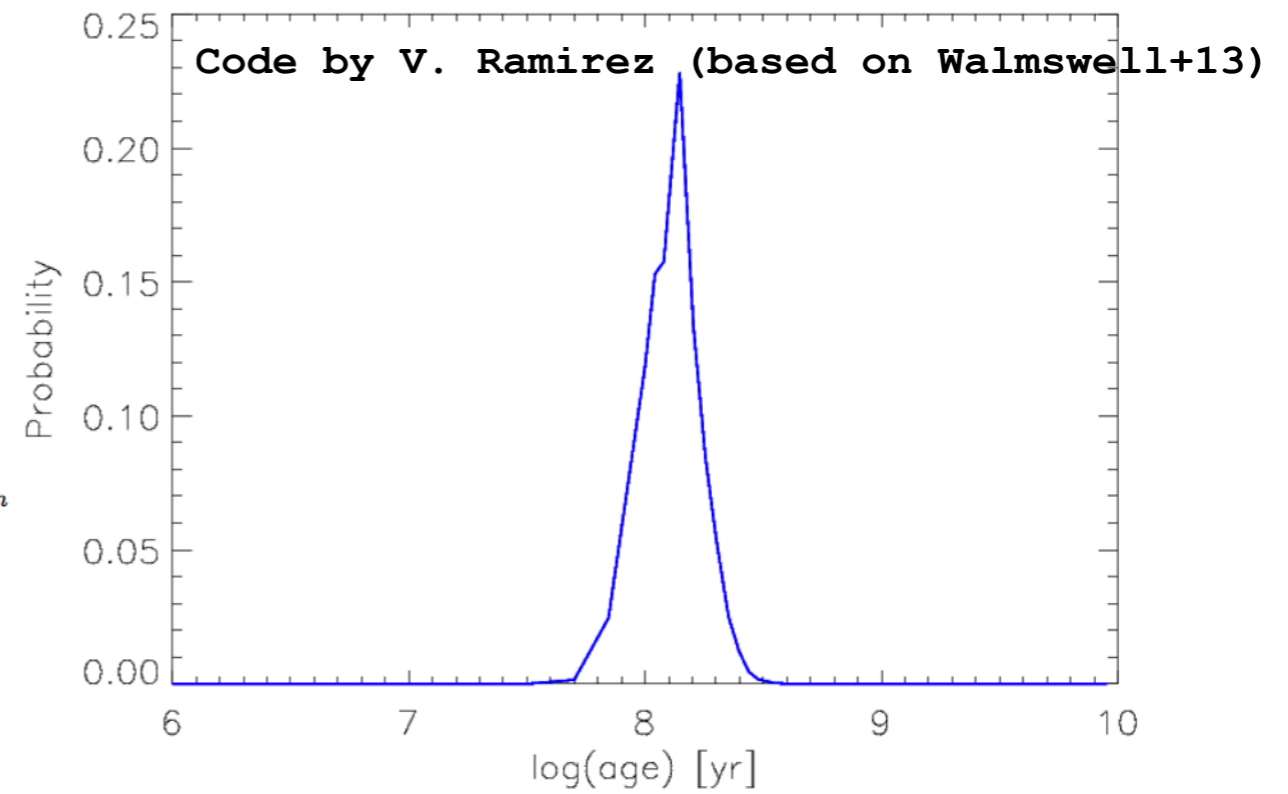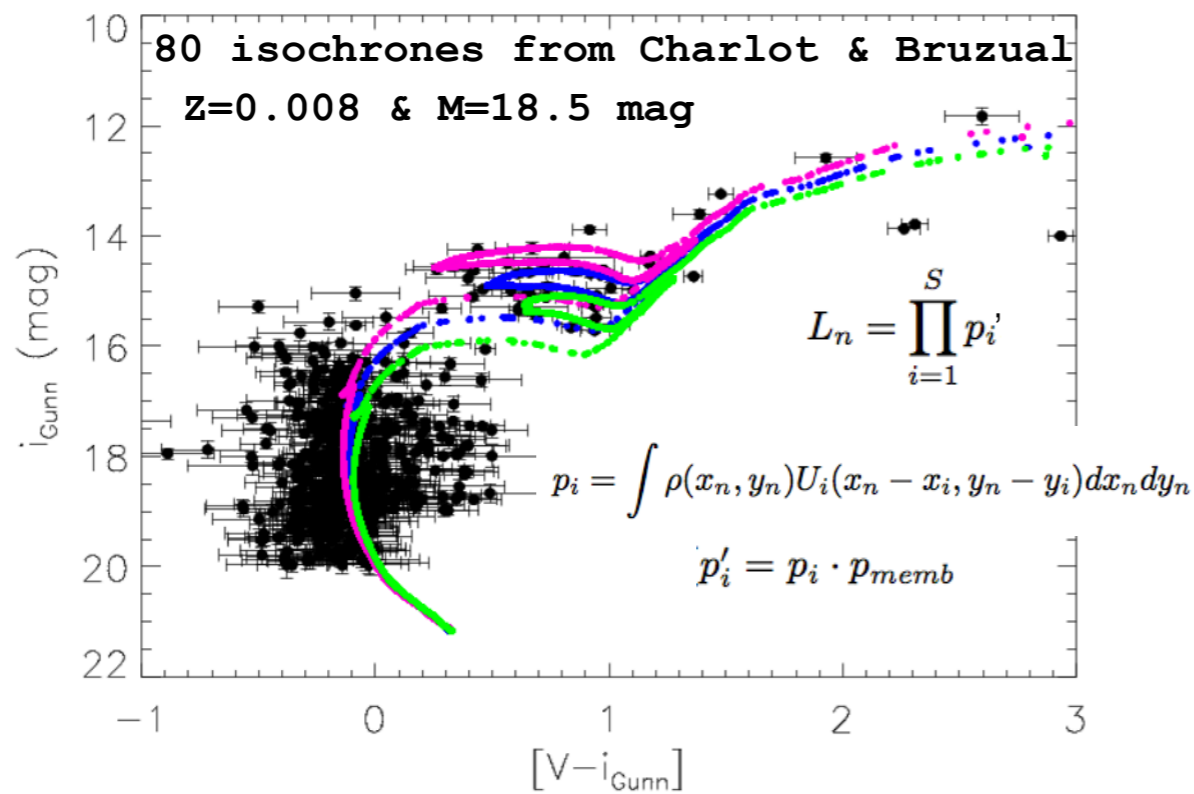
$$p_{\mathrm{memb}} = 1 - \frac{N_{*,\mathrm{field}}}{N_{*,\mathrm{cluster+field}}} \cdot \frac{A_{\mathrm{cluster}}}{A_{\mathrm{field}}}$$
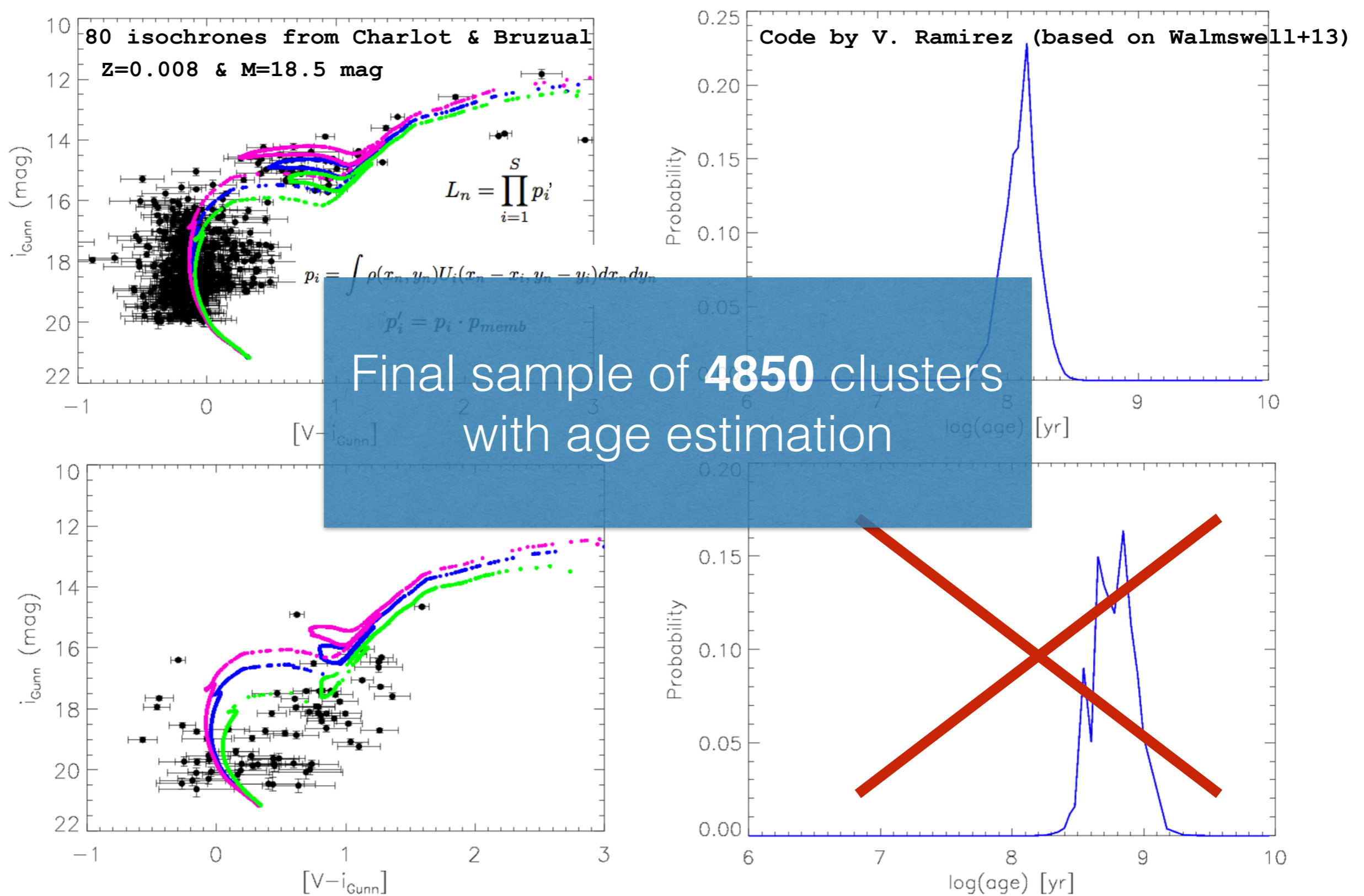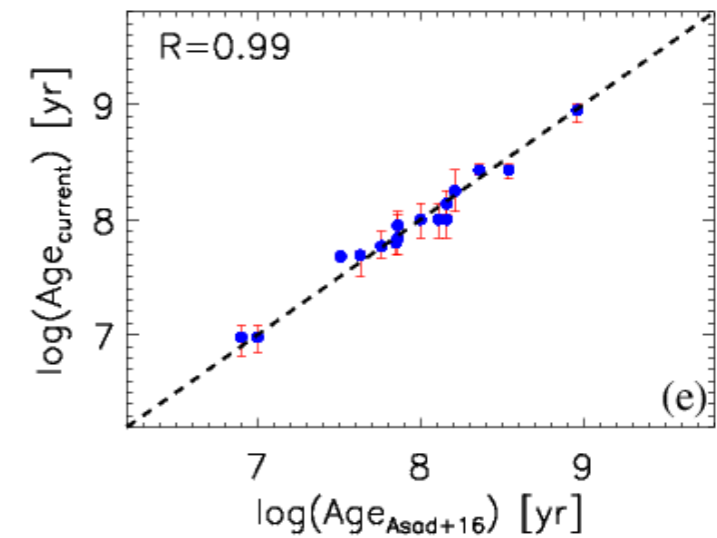
Field star de-contamination

Legend:
- $p_{memb} > 0.90$ (blue)
- $0.60 > p_{memb} > 0.90$ (green)
- $p_{memb} < 0.60$ (red)

Axes: α (J2000) horizontal, δ (J2000) vertical

Fitting isochrones

80 isochrones from Charlot & Bruzual
Z=0.008 & M=18.5 mag

$$L_n = \prod_{i=1}^{S} p_i{'}$$

$$p_i = \int \rho(x_n, y_n) U_i(x_n - x_i, y_n - y_i) dx_n dy_n$$

$$p_i' = p_i \cdot p_{memb}$$

Code by V. Ramirez (based on Walmswell+13)

Fitting isochrones

80 isochrones from Charlot & Bruzual
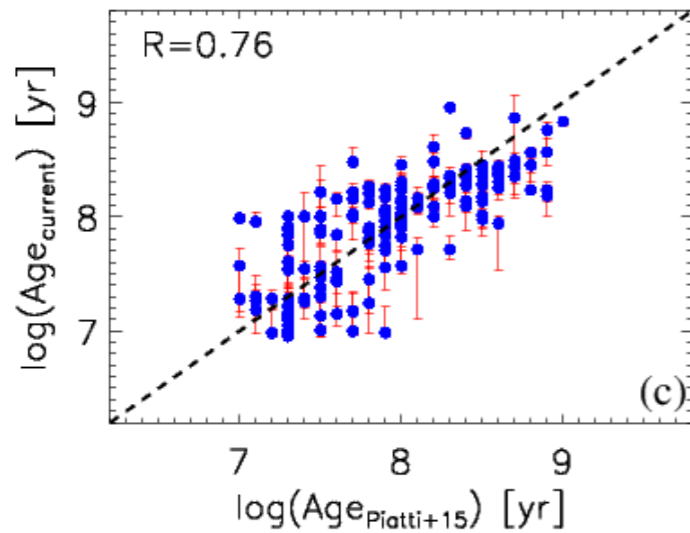Z=0.008 & M=18.5 mag

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Code by V. Ramirez (based on Walmswell+13)

Final sample of **4850** clusters
with age estimation
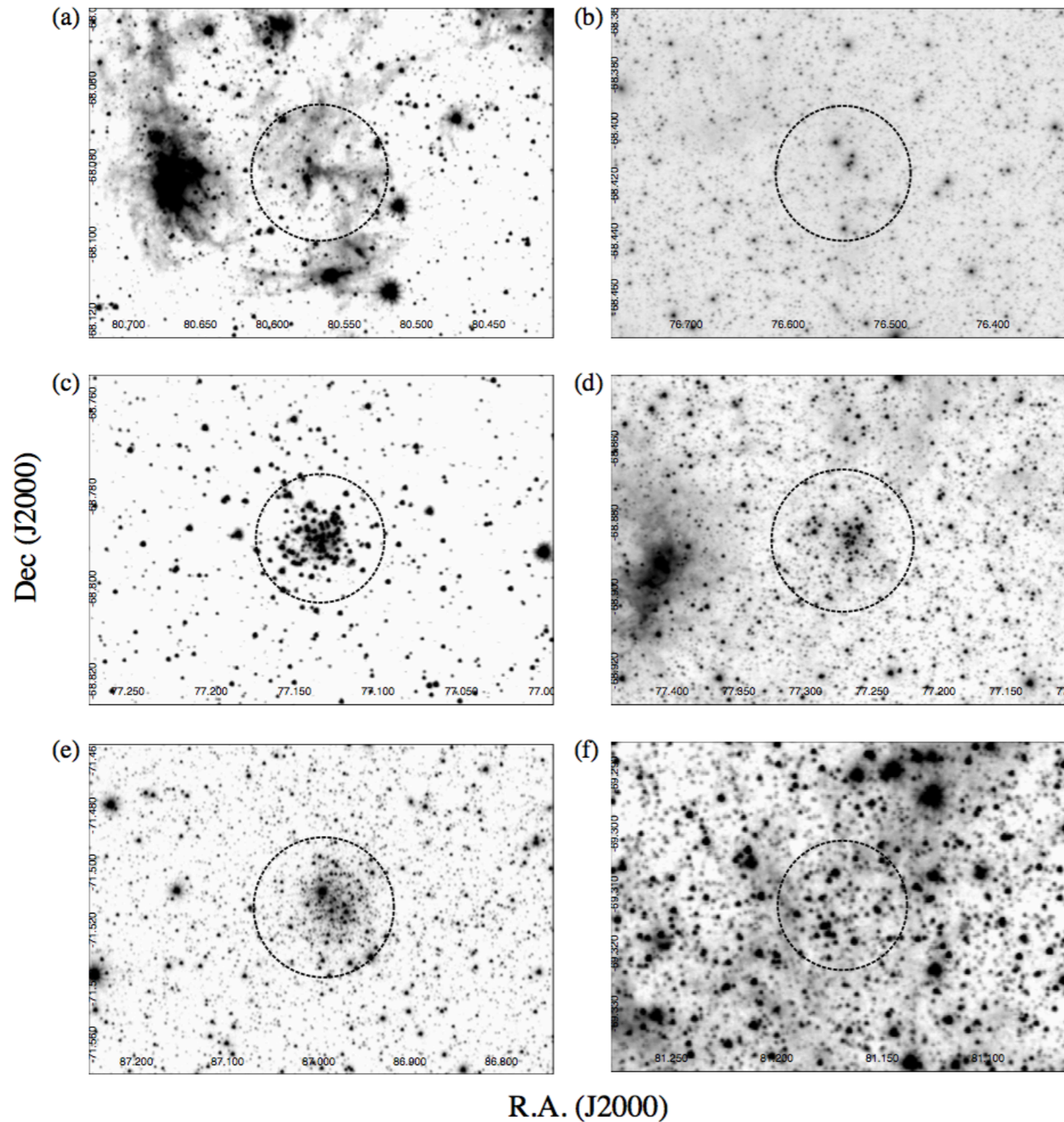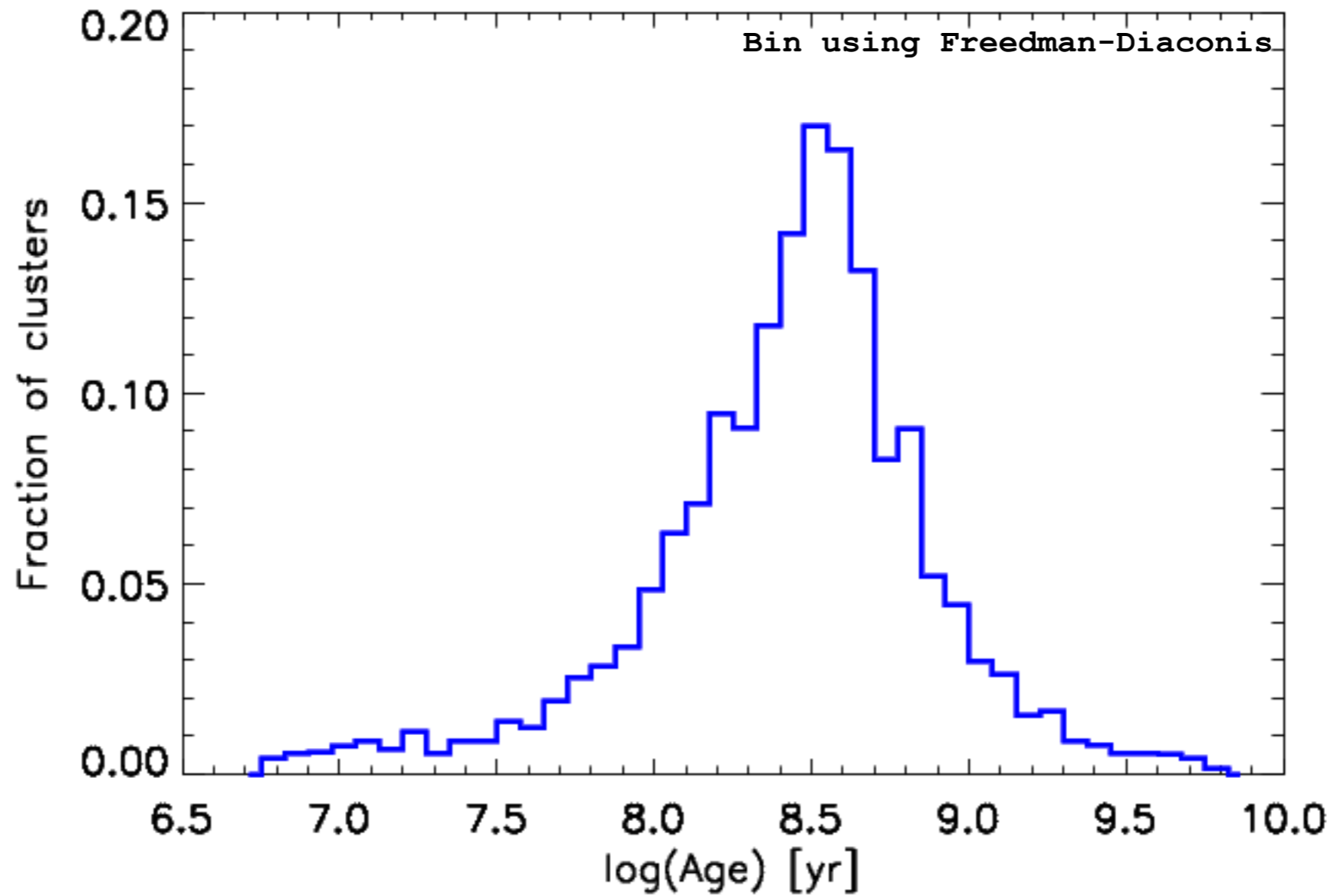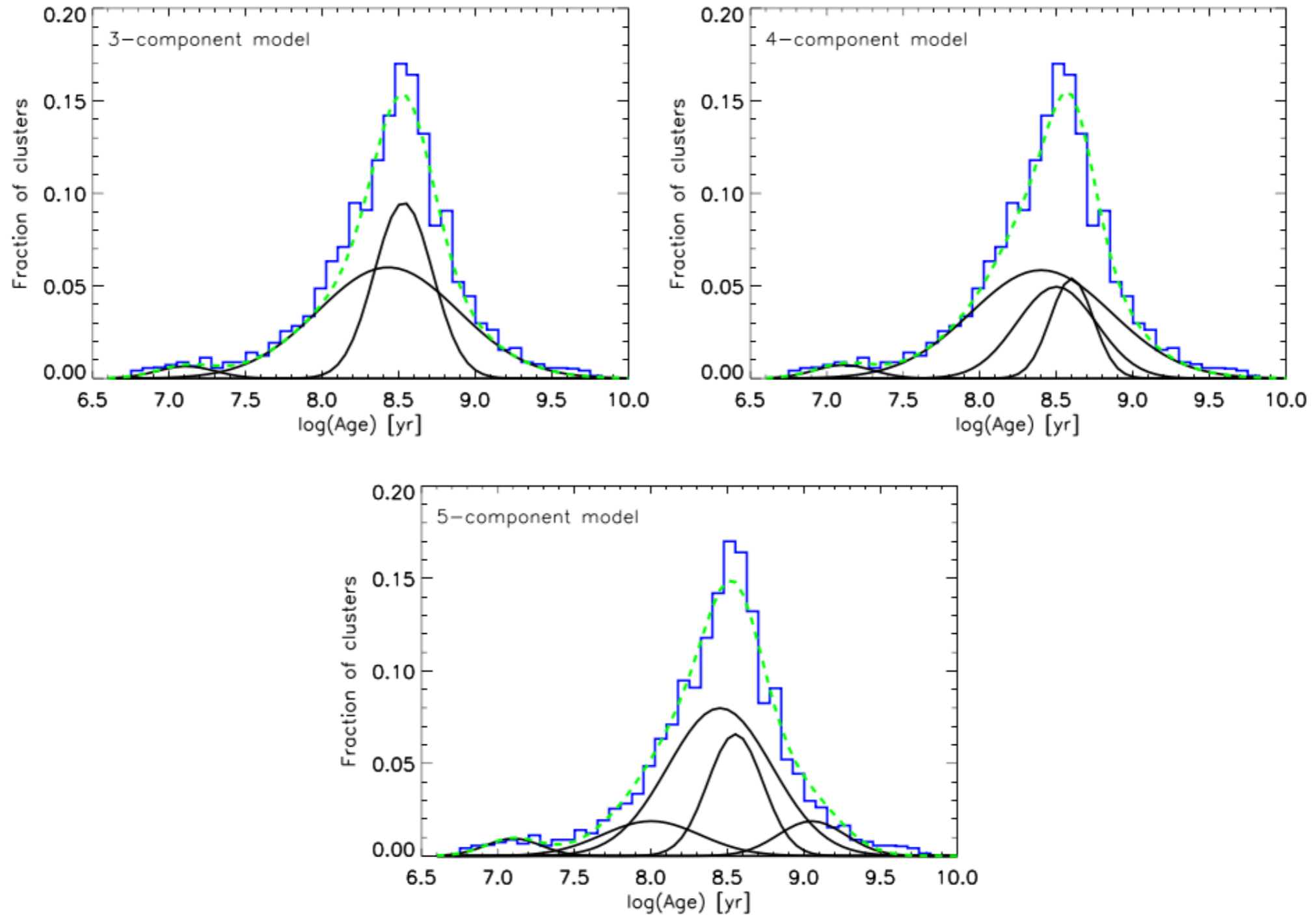
Comparisons
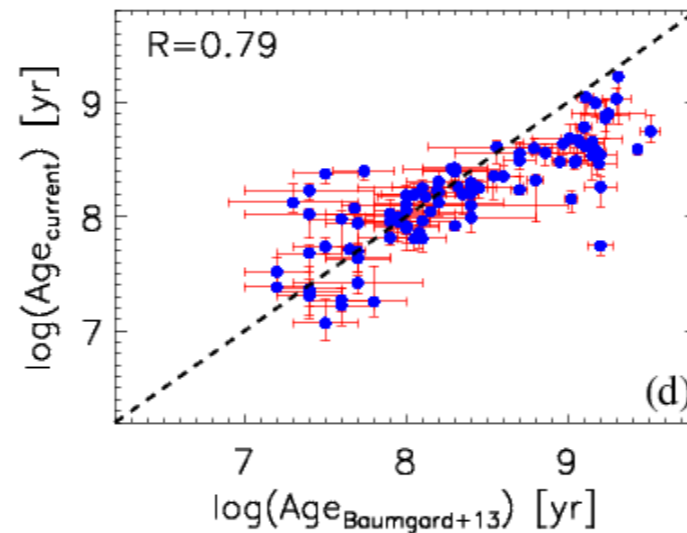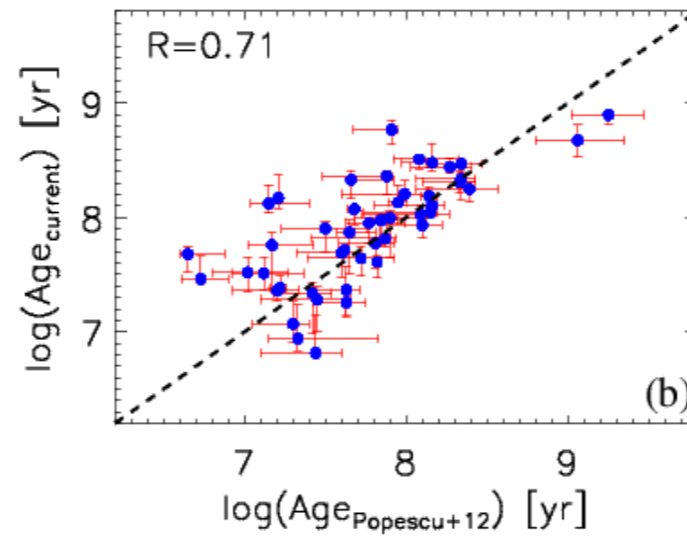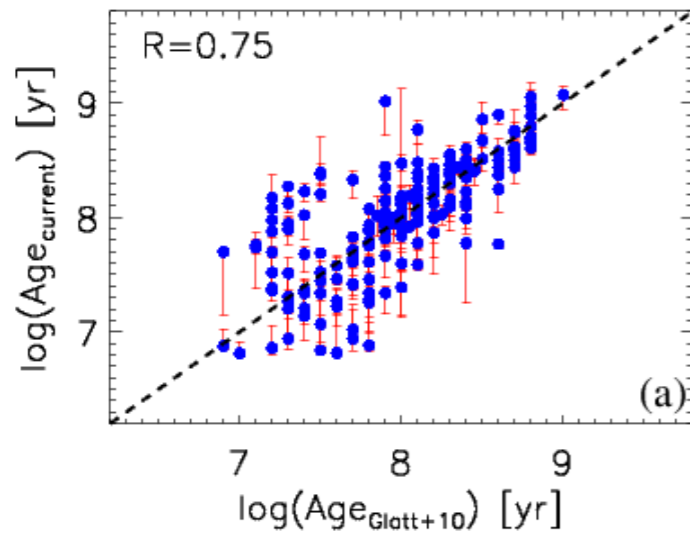
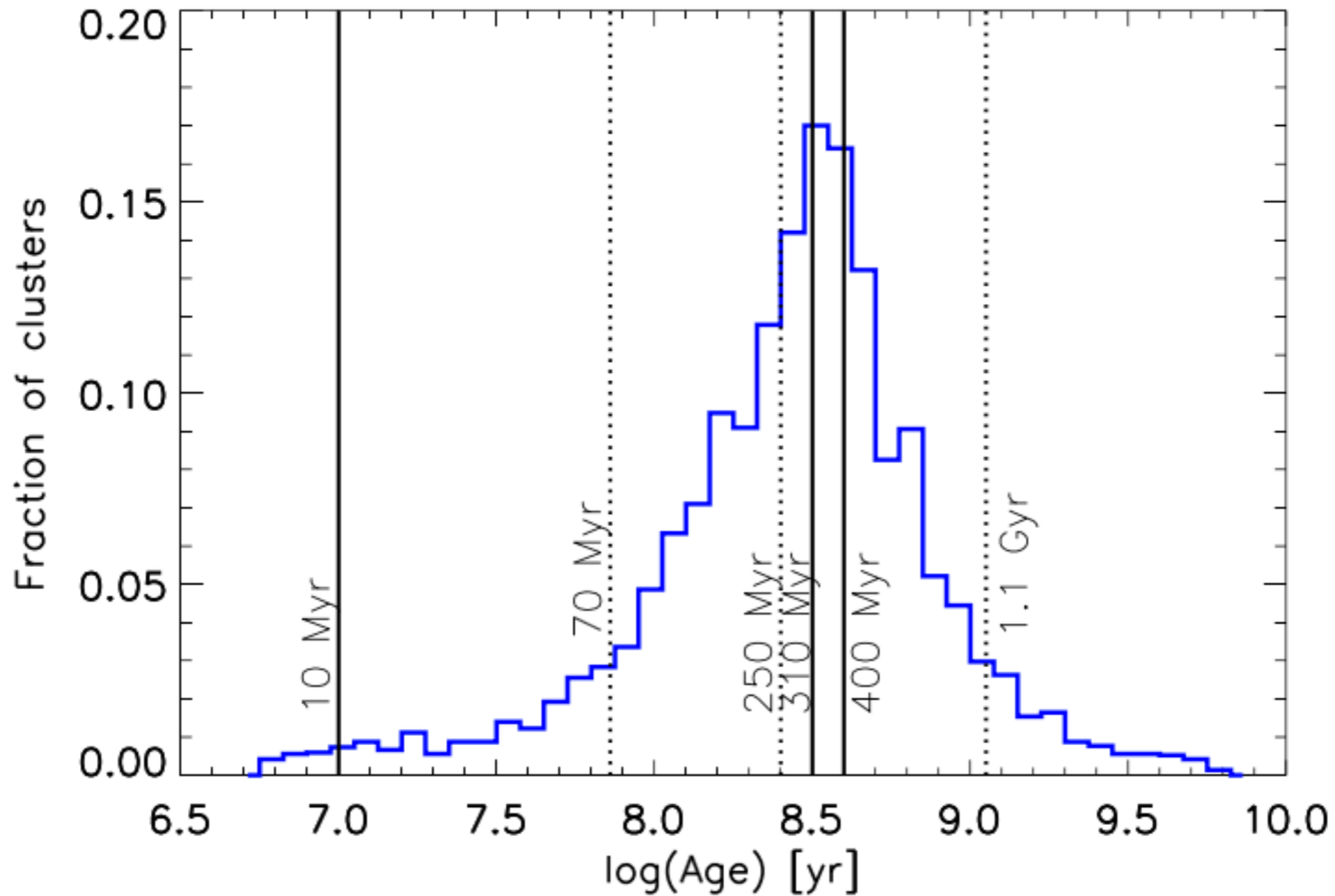# Some cluster examples

Age distribution

Age distribution

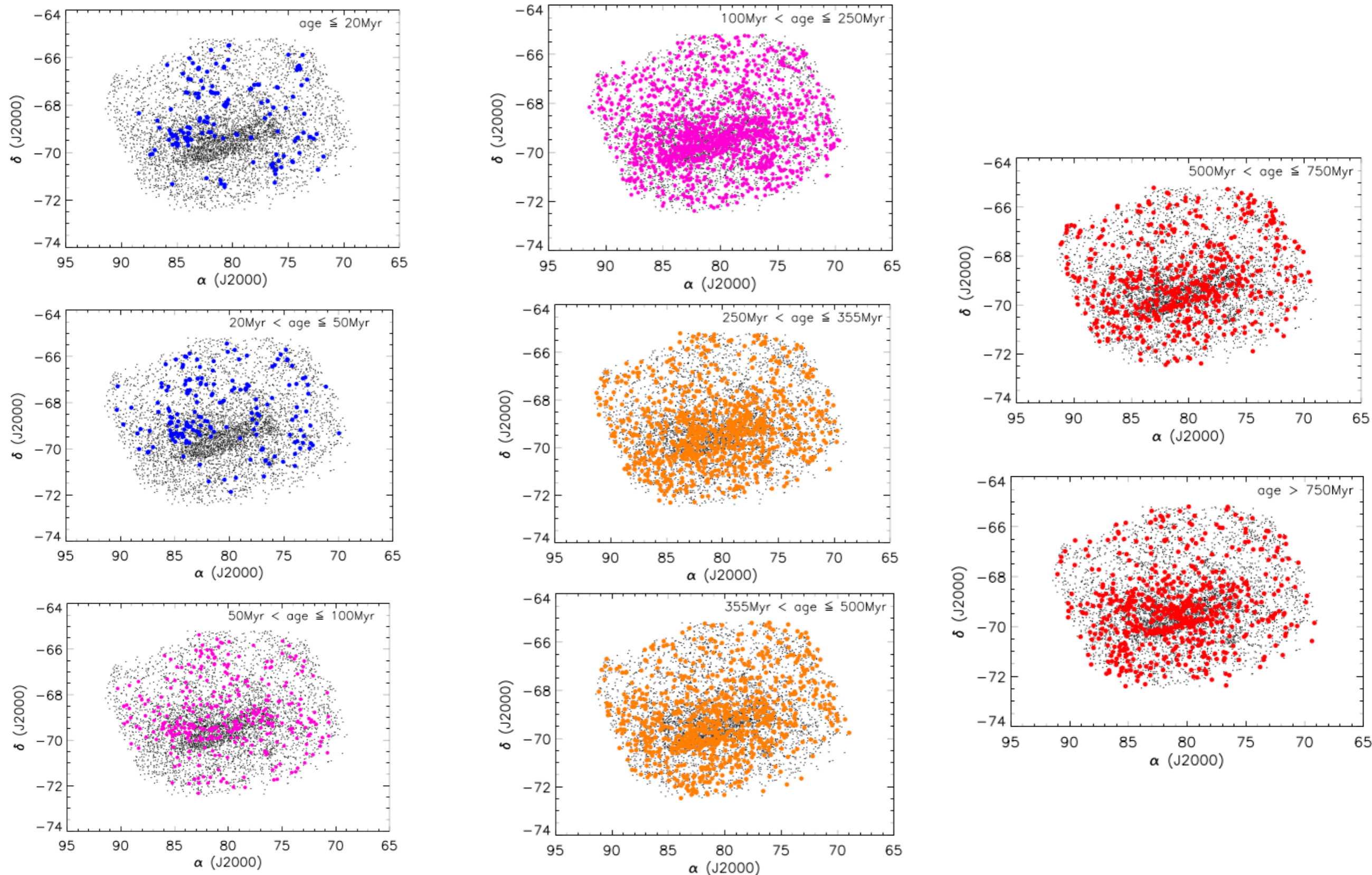**Use of Gaussian mixture models**

Age distribution

Last LMC-SMC interaction ~300-400 Myr ago
Nearest LMC peri-Galactic orbit ~40-50 Myr ago

Spatially Resolved Age Distribution

Conclusions

ABOUT THE CODE

- We have developed a new, fully **automated, method to detect and estimate the ages of clusters** in nearby galaxies.
- The method is very fast, reliable and can be applied on any kind of good-quality data; it does not require any exceptional computational power.

RESULTS ON THE LMC

- We compiled a **sample of ~5k clusters** in the LMC (**3500** of which have never been reported before)
- The distribution of ages can infer the **SCFH** of the LMC
- The above results can be used to **constrain the predictions** of N-body simulations