Unsupervised study of stellar populations in NGC 1313 and NGC 2403

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Abstract

Stellar populations in NGC 1313 and NGC 2403 galaxies were studied using multi-band photometric data obtained with the Hubble Space Telescope. Unsupervised learning techniques were applied to recognize both the stellar populations and the groups of stars in the youngest population of each galaxy. In both cases, different clustering algorithms were used and their efficiency were evaluated. Additionally, it was possible to characterize the spatial distribution of each stellar population considering their similarities with a fractal-type structure. Therefore, we identified the youngest populations with a hierarchical structure and the more evolved one with a homogeneous distribution, except for very large scale fluctuations.

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Introduction

- Galaxies are made up of diverse stellar populations
- These populations allow to know the star formation history (SFH) in the galaxy
- The high spatial resolution of the Hubble Space Telescope (HST; see Fig. 1) allows the stellar components of nearby galaxies to be separated and has generated an extensive database including photometry on various filters (Dalcanton et al. 2009; Lee et al. 2014)
- Photometric diagrams of each galaxy are a relevant tool to identify the different stellar populations, although their separation is a complex task.
- There are several methods in unsupervised machine learning that allow to group data based on common characteristics ("clustering")

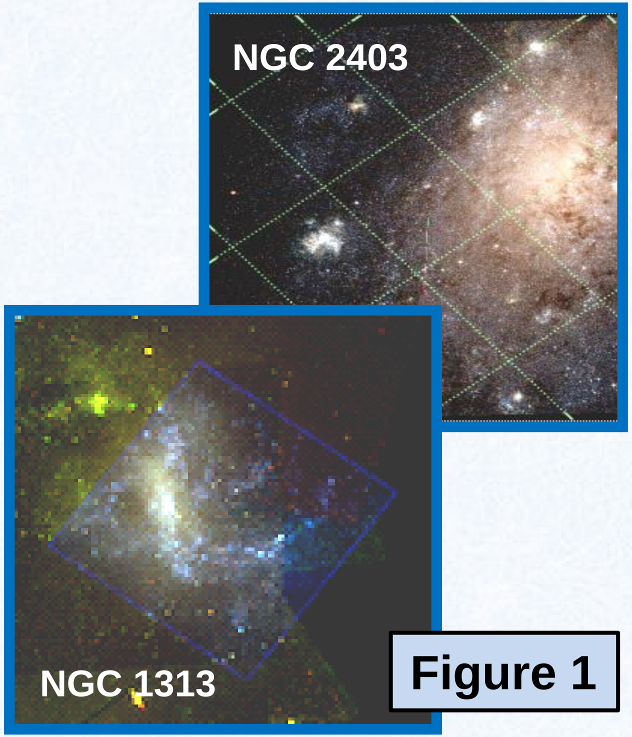


Figure 1

Color images of NGC 1313 and NGC 2403 galaxies. Based on data from the *"HST Legacy Extragalactic UV Survey"* andl *"The ACS Nearby Galaxy Survey"*

Methodology

Color-magnitude diagrams (CMDs) and color-color diagrams (TCDs) of nearby galaxies have been obtained from multiband HST observations.

- Data were pre-processed and then bright objects (V <24) were separated from faint objects (V> 24). Using the CMDs and TCDs, different stellar components were identified using GMM (see Fig. 2)

- Different gaussian components were grouped together with "K-Means" method applied to their corresponding centers in TCDs. Two main stellar populations were identified: "blue population" and "red population".

- Different clustering methods were applied on the spatial distribution of the bright objects of the "blue population" and their most relevant parameters were evaluated (see Fig. 3).

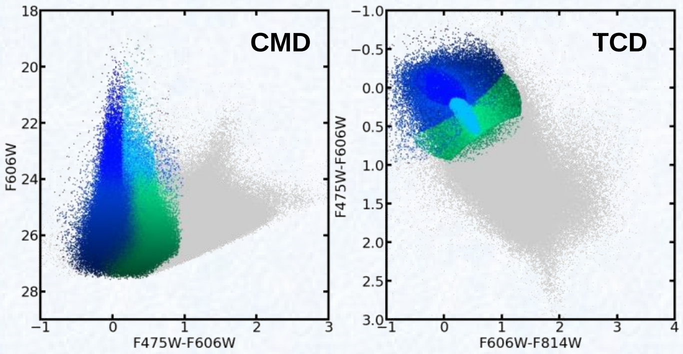
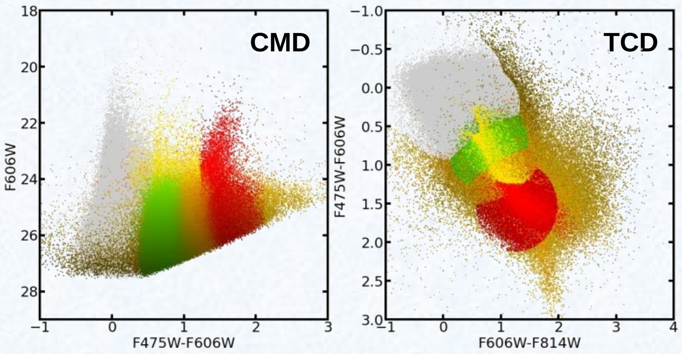
Clustering methods

- **GMM:** *Gaussian mixture method*
- **K-Means**
- **AgC:** *Agglomerative clustering*
- **DBSCAN:** *Density based spatial clustering of applications with noise*
- **HDBSCAN:** *Hierarchical DBSCAN*
- **PLC:** *Path linkage criterion*

See details in Battinelli et al. 2000, Pedregosa et al. 2011 and McInnes et al. 2017

Note: *V* magnitude corresponds to F555W or F606W magnitudes depending on the available data for each galaxy

Results: Photometric diagrams (CMDs y TCDs) of studied galaxies

<table>
<tr><th>Galaxy</th><th>Filters</th><th>Blue population (GMM)</th><th>Red population (GMM)</th></tr>
<tr><td>NGC 2403</td><td>- F435W
- F475W
- F606W
- F814W</td><td></td><td></td></tr>
<tr><td>NGC 1313</td><td>- F275W
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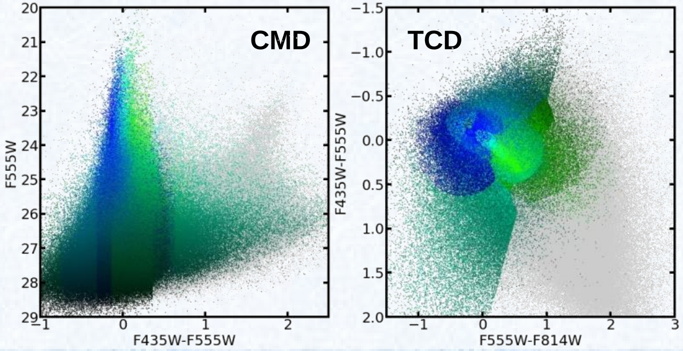
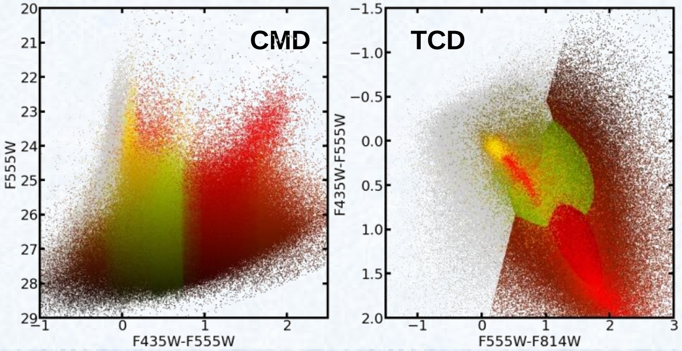
- F435W
- F555W
- F814W</td><td></td><td></td></tr>
</table>

Figure 2

Note: Colors indicate different gaussian stellar components

Results: Obtainded parameters using different clustering methods aplied to blue population objects in each galaxy

- All methods, except AgC, identify stellar clusters linked to stellar over-densities
- DBSCAN clusters are small and with low size dispersion
- HDBSCAN and PLC provide stellar groups with a wide range of sizes
- Clusters provided by all methods have Silhouette indices (Rousseeuw 1987) with acceptable values

NGC 2403

	AgC	DBSCAN	HDBSCAN	PLC
N_{CL}	603	585	472	446
R_{med}	4.3"	0.3"	2.2"	1.4"
σ_R	1.4"	0.1"	1.4"	0.7"
Silhouette	0.39	0.55	0.53	0.36

NGC 1313

	AgC	DBSCAN	HDBSCAN	PLC
N_{CL}	916	854	925	697
R_{med}	2.4"	0.2"	1.2"	1.1"
σ_R	1.0"	0.1"	1.1"	0.7"
Silhouette	0.43	0.63	0.57	0.38

Note: N_{CL} = Number of clusters; R_{med} = Mean radius; σ_R = Radius dispersion

Results: Identified stellar clusters from the "blue population" at each galaxy

NGC 2403

NGC 1313

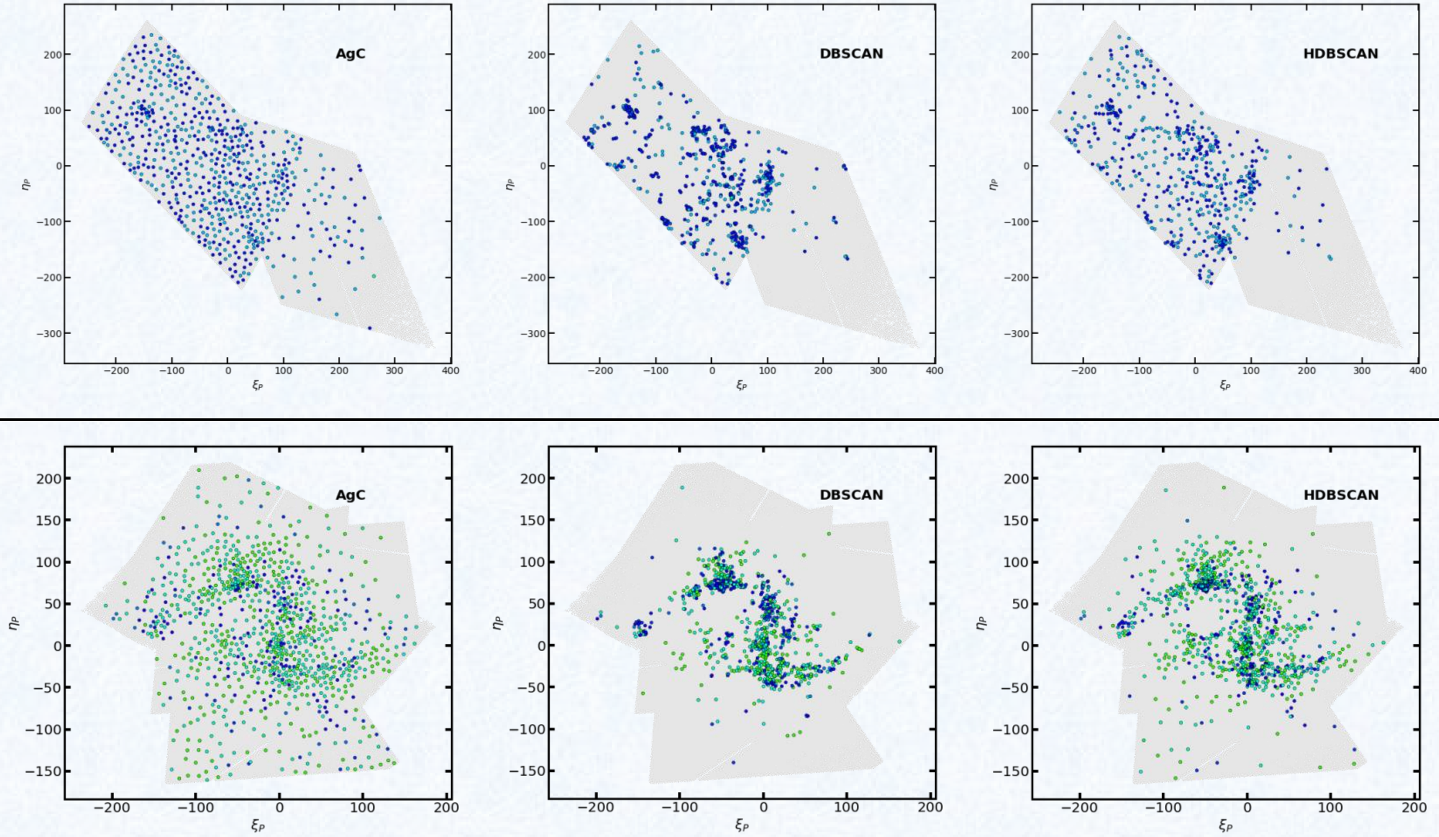


Figure 3

Preliminary conclusions

- Stellar populations of NGC 2403 and NGC 1313 galaxies were discriminated based on the photometric diagrams of high spatial resolution of the HST
- Using different methods, the stellar groups associated with the so-called "blue population" and "red population" have been identified.
- “Blue population" appears to have a fractal structure with an associated dimension D ~ 1.6, while the "red population" is homogeneous except for very large-scale fluctuations.
- HDBSCAN and PLC methods are the most appropriate to identify stellar clusters

Future prospects

- Refinement of the methodology used considering other variants in the selection of objects in the CMDs and in the modeling of the distributions in all the diagrams.
- Association between the components found and the evolutionary phases of the objects.
- Application of the procedure to a large sample of nearby galaxies using the same type of data.

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