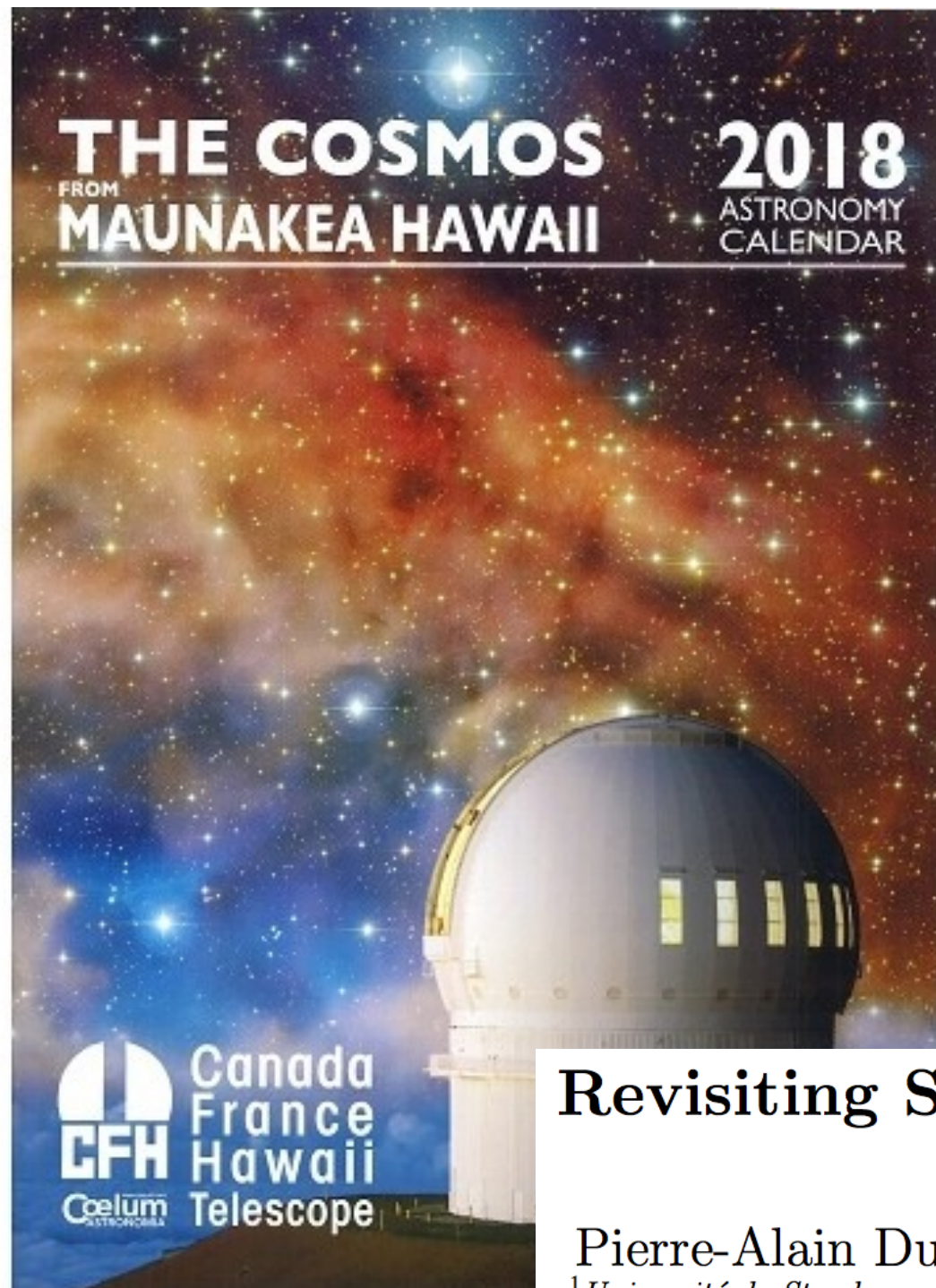


**Studying the formation and evolution of galaxies with deep imaging**

**Avenues and issues with the exploration of the low surface brightness universe**





## Deep imaging with the Canada-France-Hawaii Telescope

### Revisiting Stephan's Quintet with deep optical images

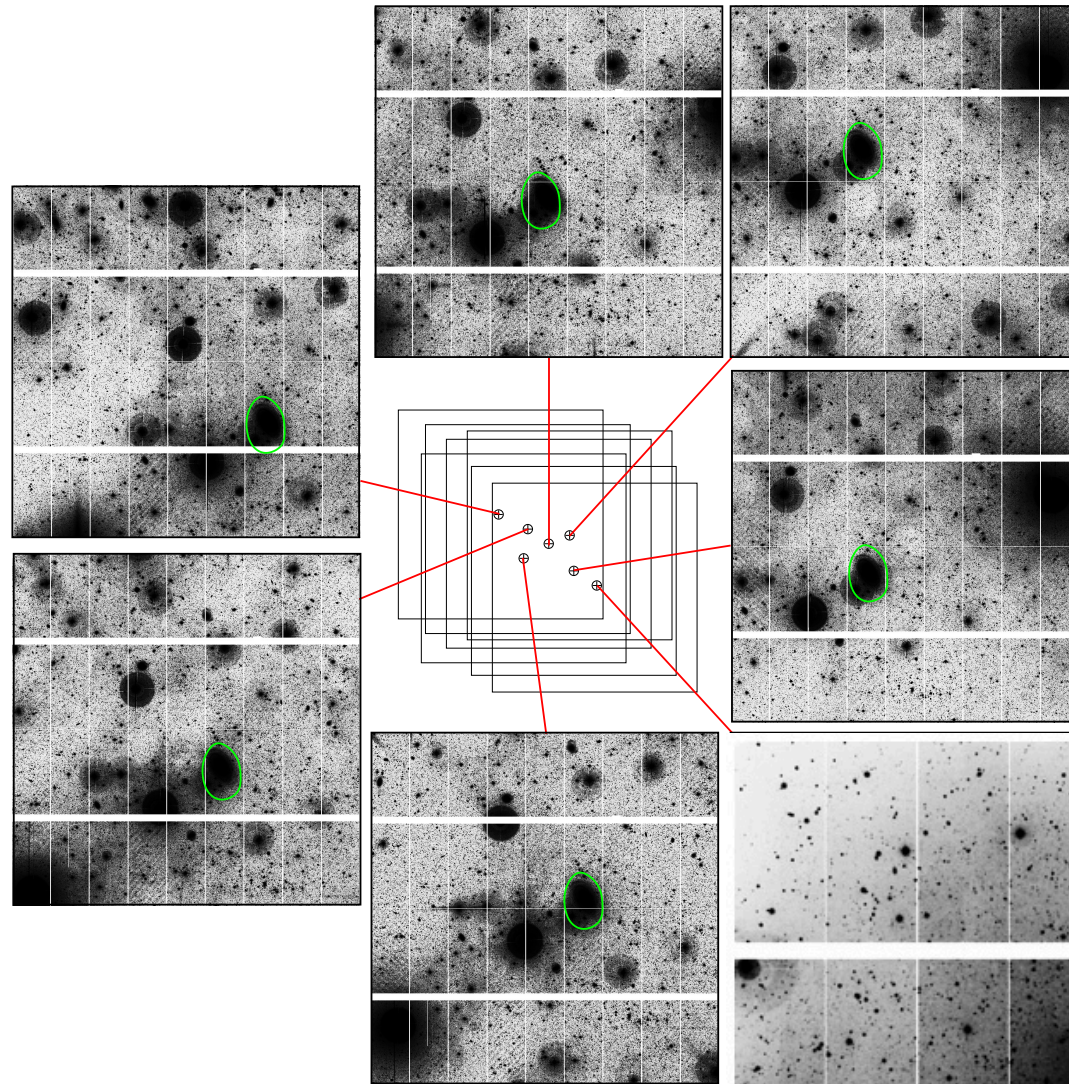
Pierre-Alain Duc,<sup>1</sup>★ Jean-Charles Cuillandre <sup>2</sup> and Florent Renaud <sup>3</sup>

<sup>1</sup>*Université de Strasbourg, CNRS, Observatoire astronomique de Strasbourg, UMR 7550, F-67000 Strasbourg, France*

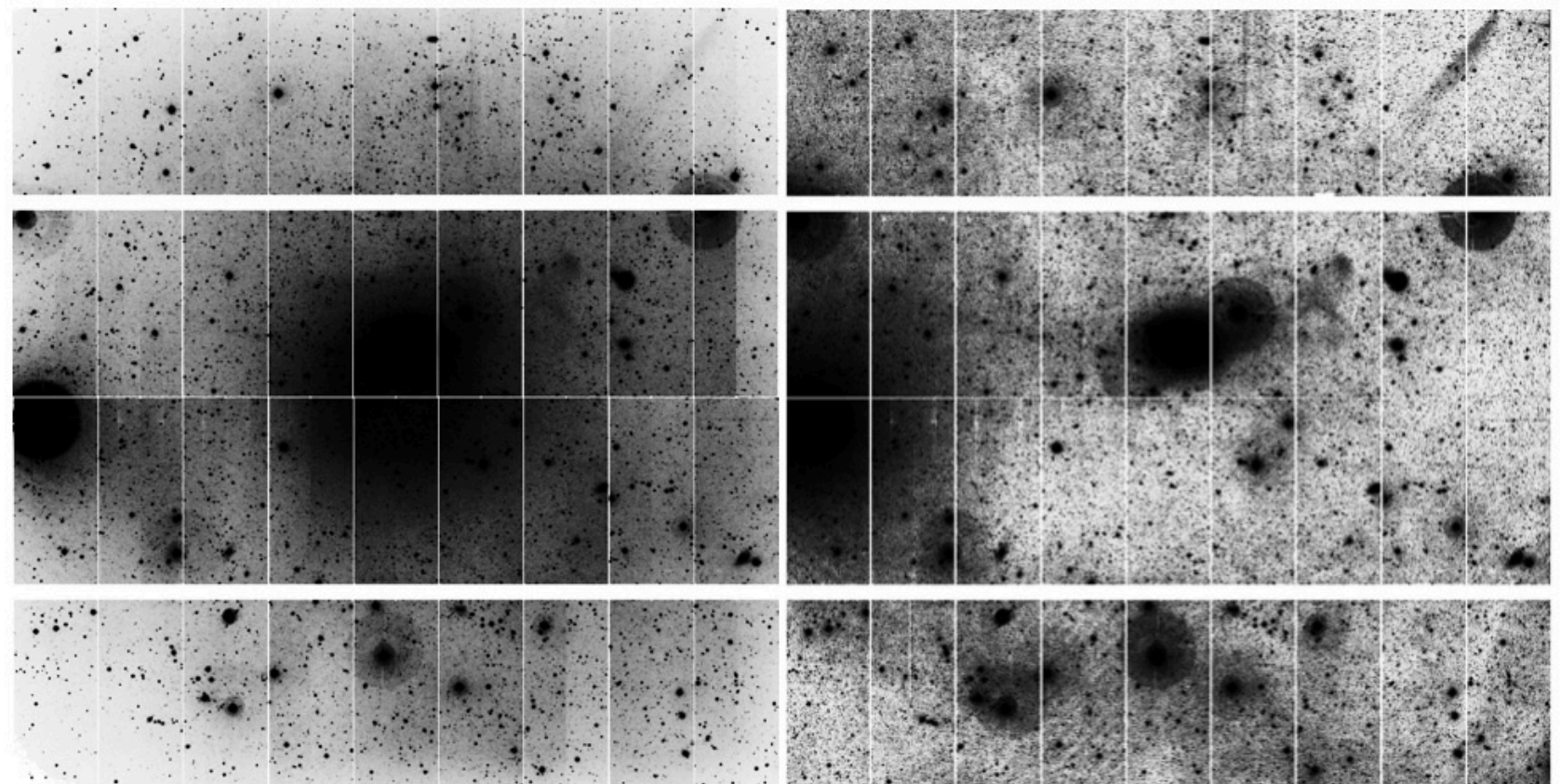
<sup>2</sup>*IRFU, CEA, Université Paris-Saclay, Université Paris Diderot, AIM, Sorbonne Paris Cité, CEA, CNRS, Observatoire de Paris, PSL Research University, F-91191 Gif-sur-Yvette Cedex, France*

<sup>3</sup>*Department of Astronomy and Theoretical Physics, Lund Observatory, Box 43, SE-221 00 Lund, Sweden*





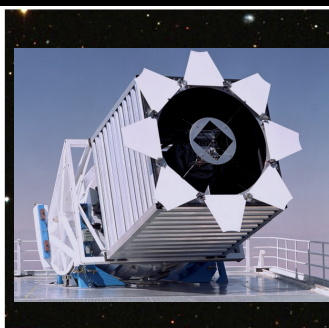
MegaCam @ CFHT



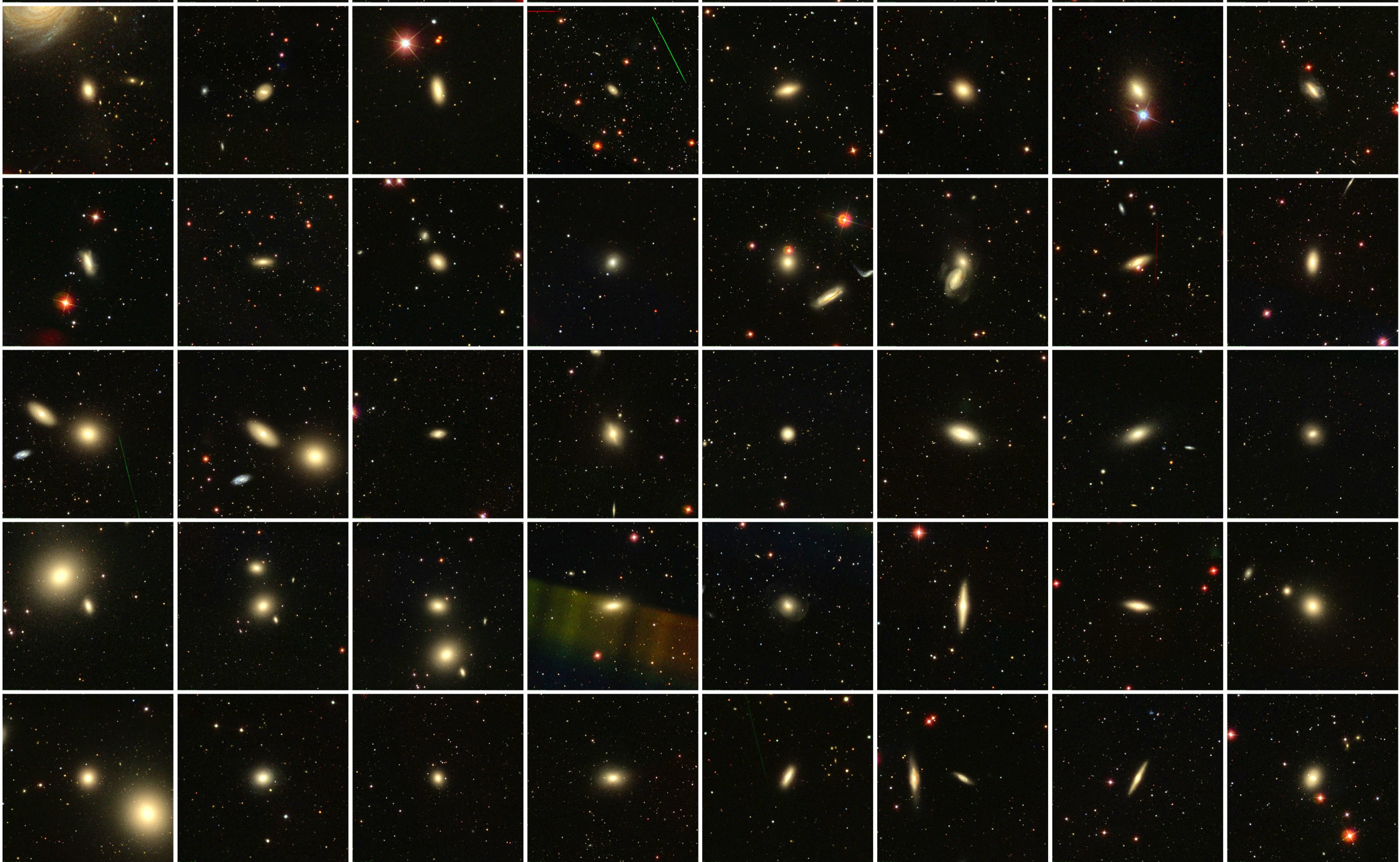
Duc, **Cuillandre** et al., 2015

- **Issue 1:** dealing with modern CCD arrays and complex optical cameras: the need for an optimized observing strategy to remove instrumental artefacts





SDSS





*MATLAS*

Deep imaging of 260 massive early-type galaxies

**NGVS**

MegaCam

Deep imaging at  $29 \text{ mag.arcsec}^{-2}$





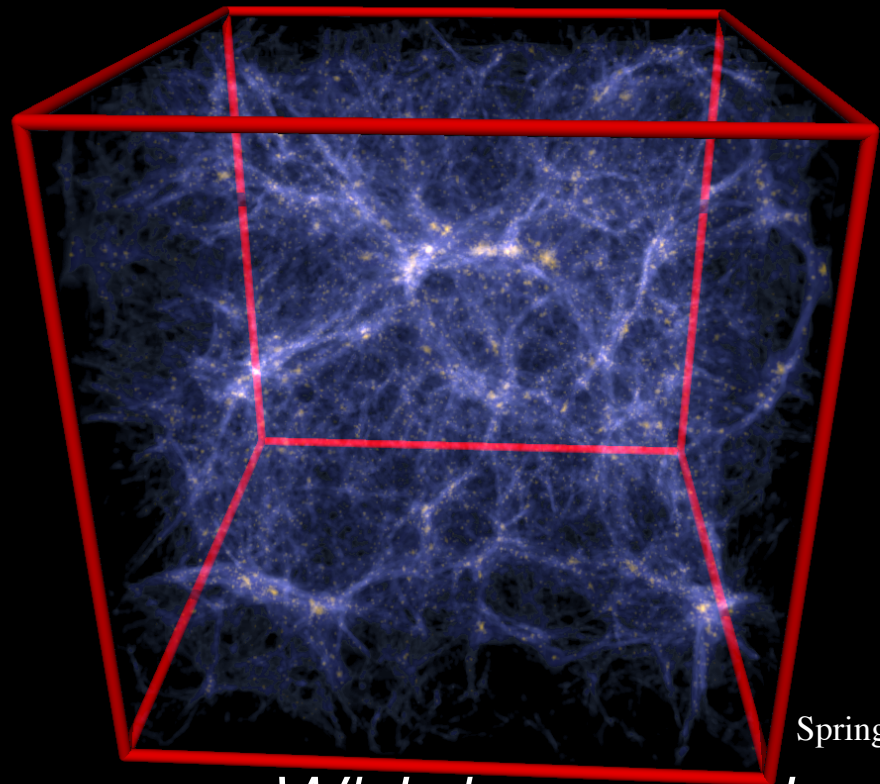
**Exploring the LSB Universe: building massive galaxies**





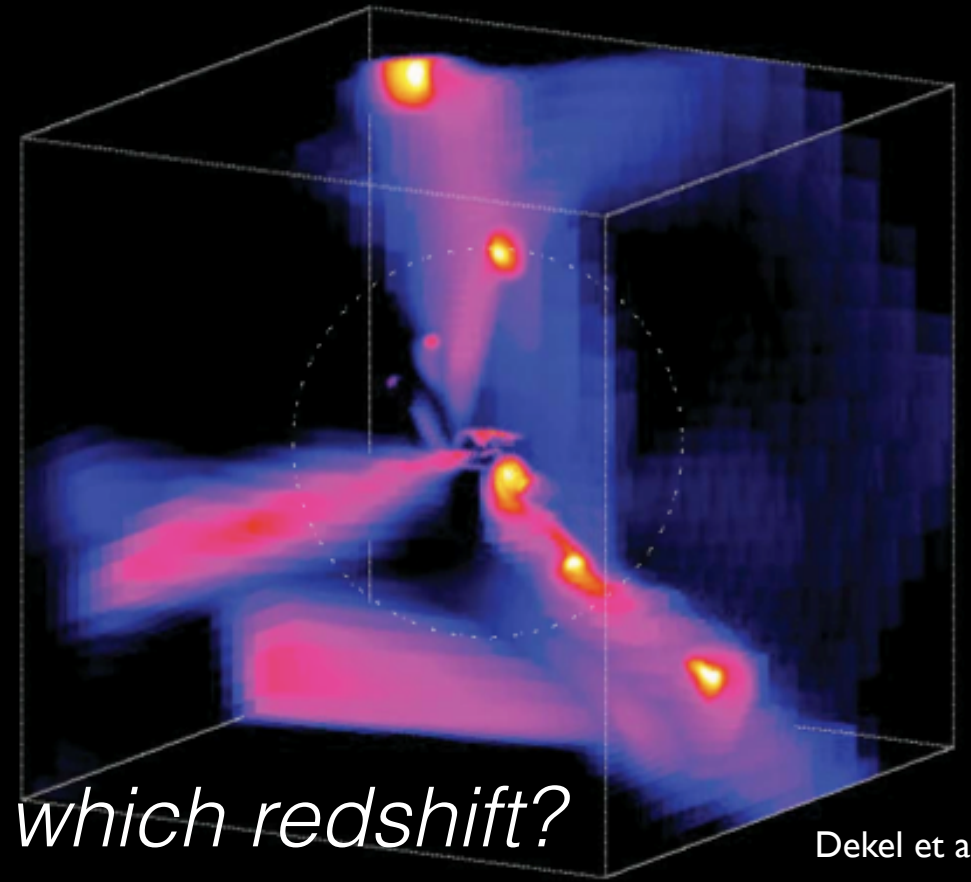
# Motivations: two scenarios for the formation of massive galaxies

*Merger based*



Springel et al, 2013

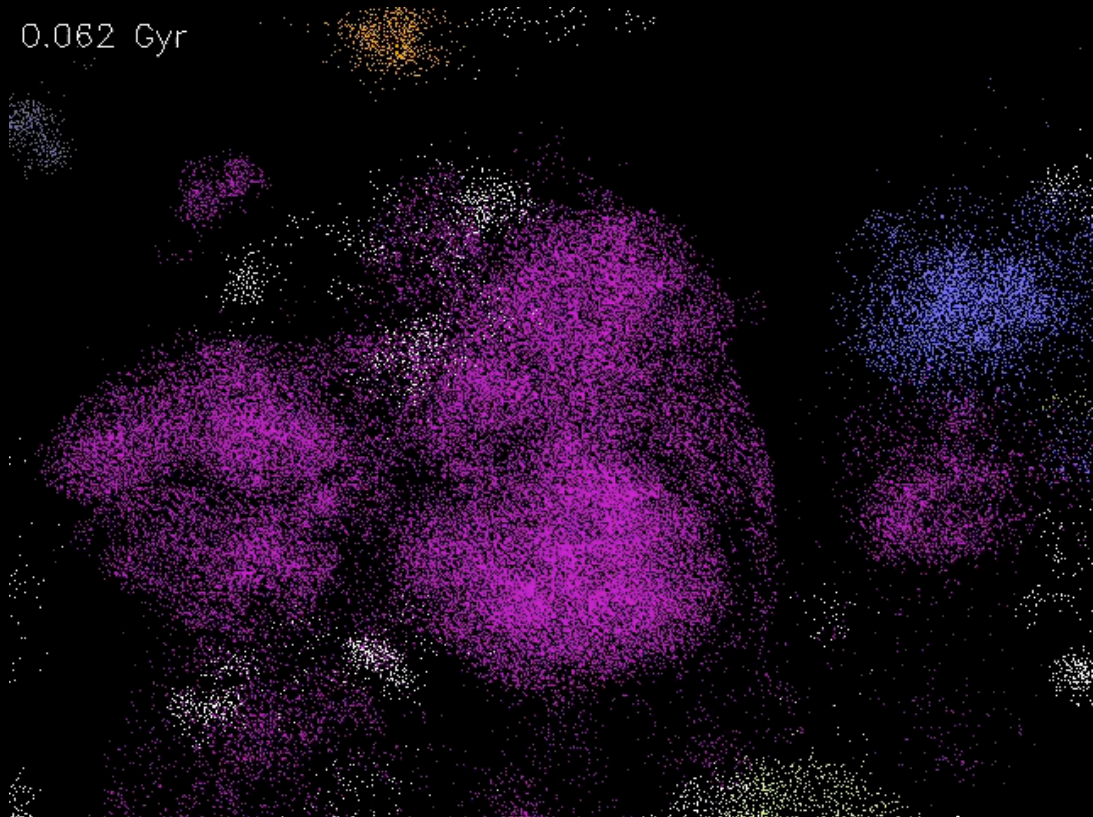
*Accretion based*



Dekel et al.

*Which scenario dominates ... at which redshift?*

0.062 Gyr



Aquarius, Helmi et al.



Bournaud et al.





**Exploring the LSB Universe: building massive galaxies**





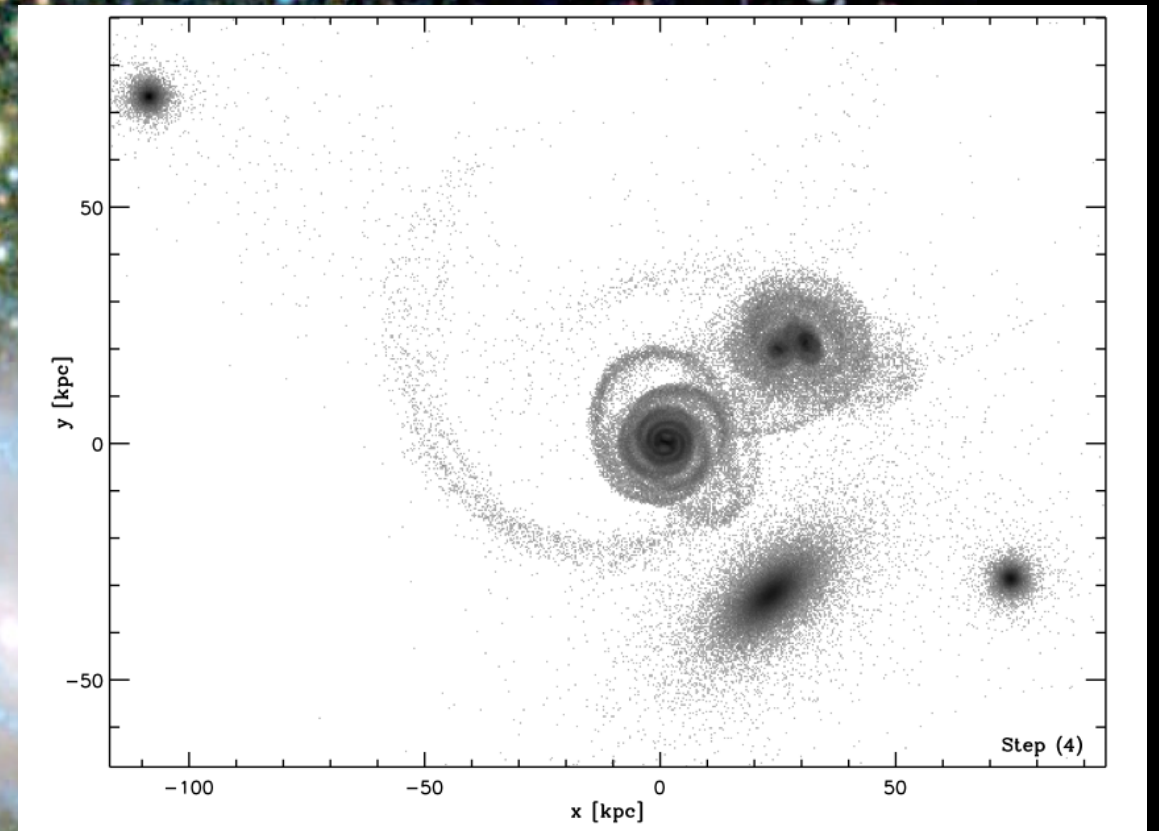
# Exploring the LSB Universe: looking for tidal features galaxies



**Stephan's Quintet:** a compact group of ~~5~~ 4 5 galaxies



# Exploring the LSB Universe: looking for tidal features galaxies



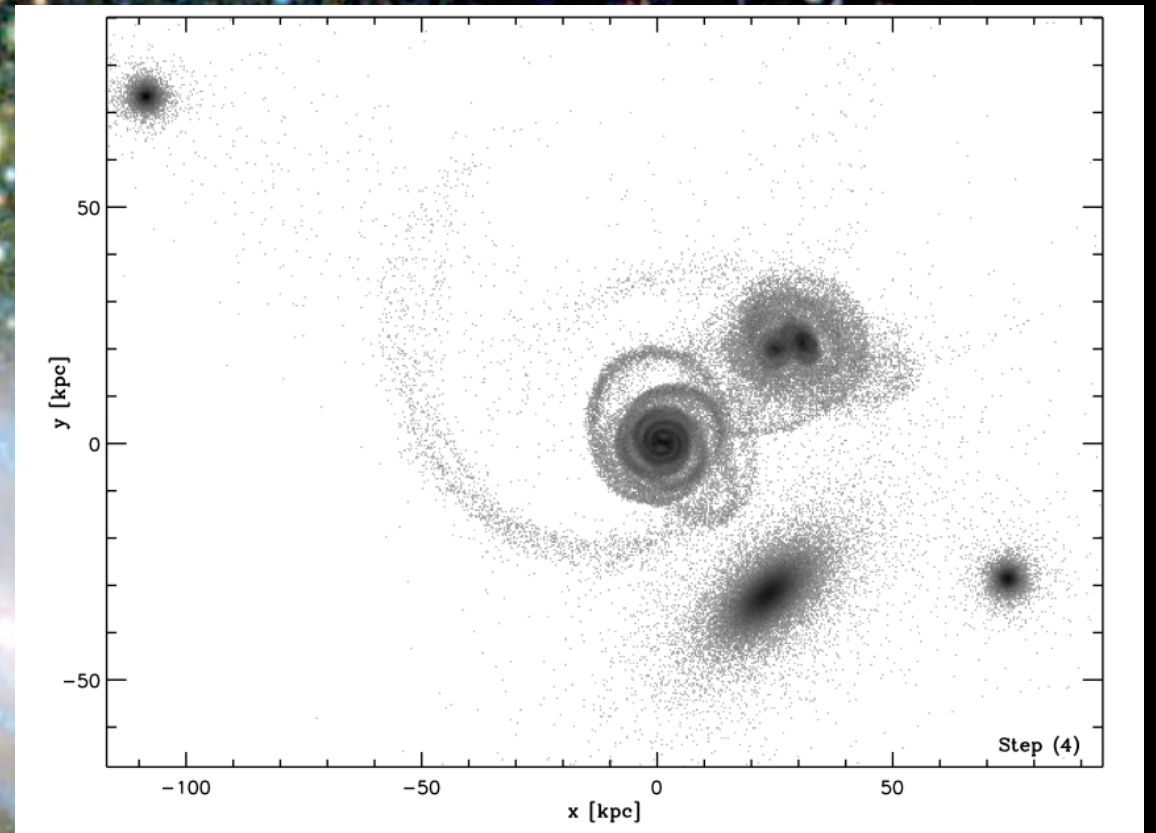
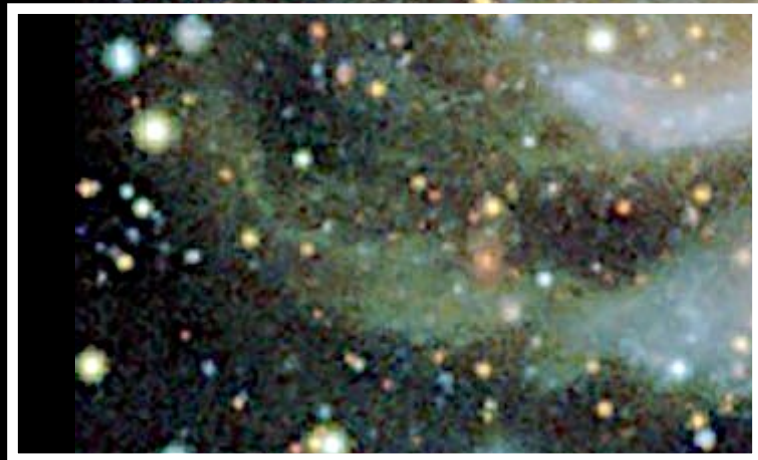
Renaud et al., 2010

Stephan's Quintet: reproducing the past mass assembly of the group



# Looking for tidal features

NGC 7320c



Renaud et al., 2010

Stephan's Quintet: reproducing the past mass assembly of the group



Classification

NGC5557

Login : paduc

Submit

Classify

Check

Fine structures

Tidal tails

No

Likely

Yes

Unsure

Number of tails

3

Long tidal tails with TDGs on each side of the galaxy

Stellar streams

No

Likely

Yes

Unsure

Number of streams

0

Shells

No

Likely

Yes

Unsure

Number of shells

3

Contaminants

Cirrus

No

Weak

Strong

Unsure

Navigate:

Issue 2: LSB structures identification and classification

RA,Dec 14:18:25.681 +36:21

Qualitatively, by eye, from a group of experts

2' 20 kpc

© MATLAS NGC5557



# LSB structures identification and classification

What feature will you draw? ▾

RA: 170.309, Dec: 57.84

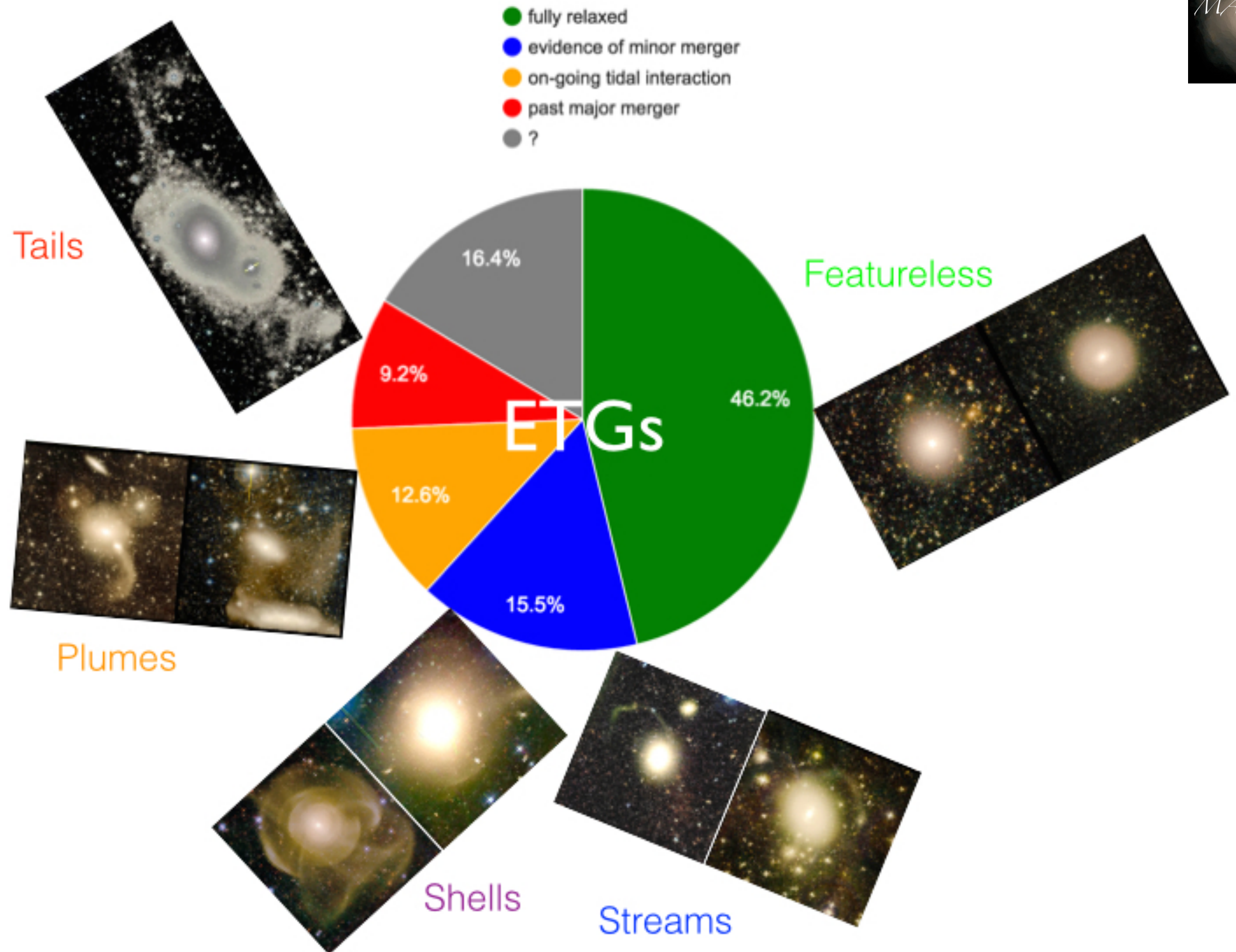
Shape	ID	Feature	Note
	0	Streams	+
	1	Shells	+
	2	-	+

Quantitatively, with manual **annotation** by trainees

Submit

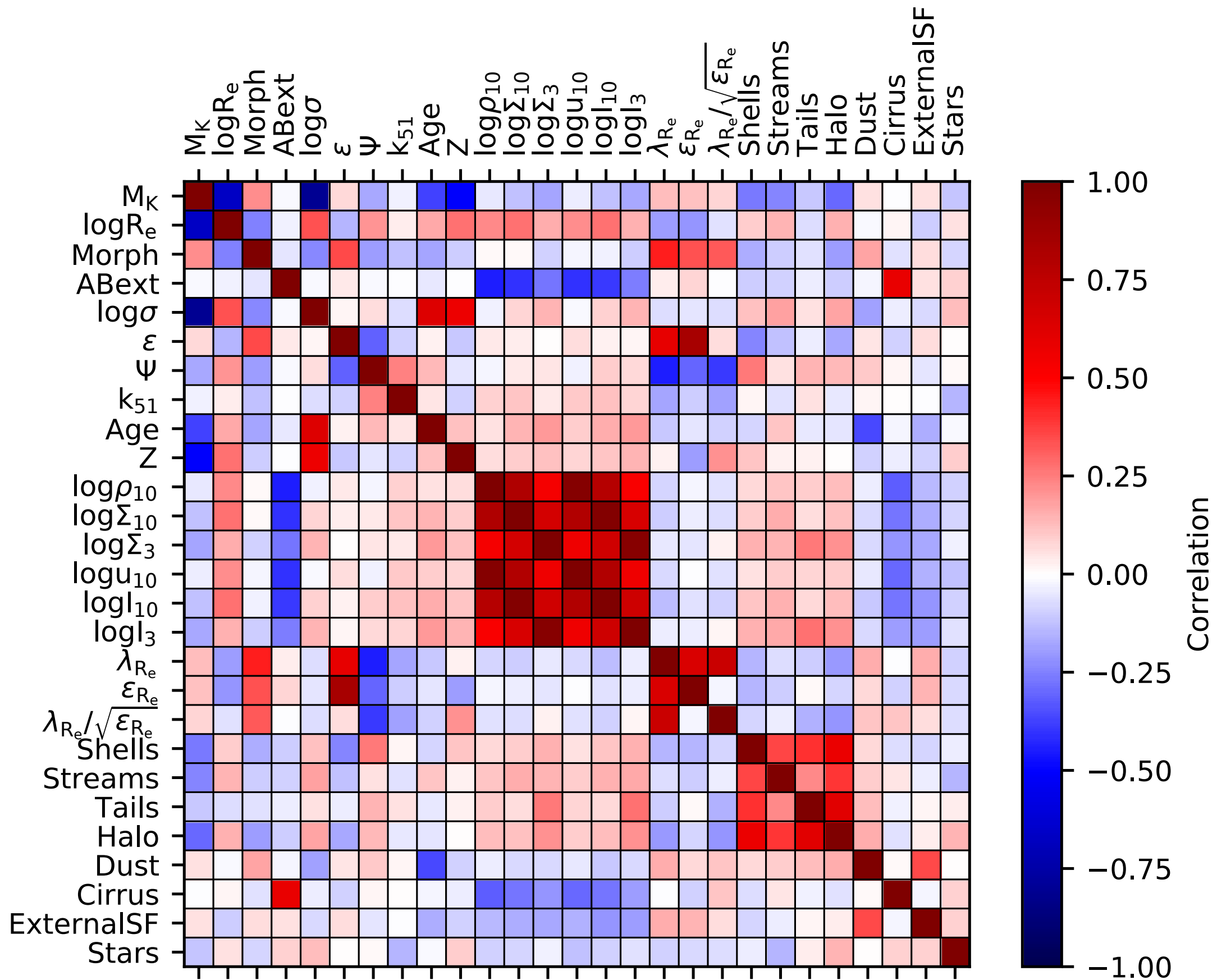
In preparation of **deep learning** experiments





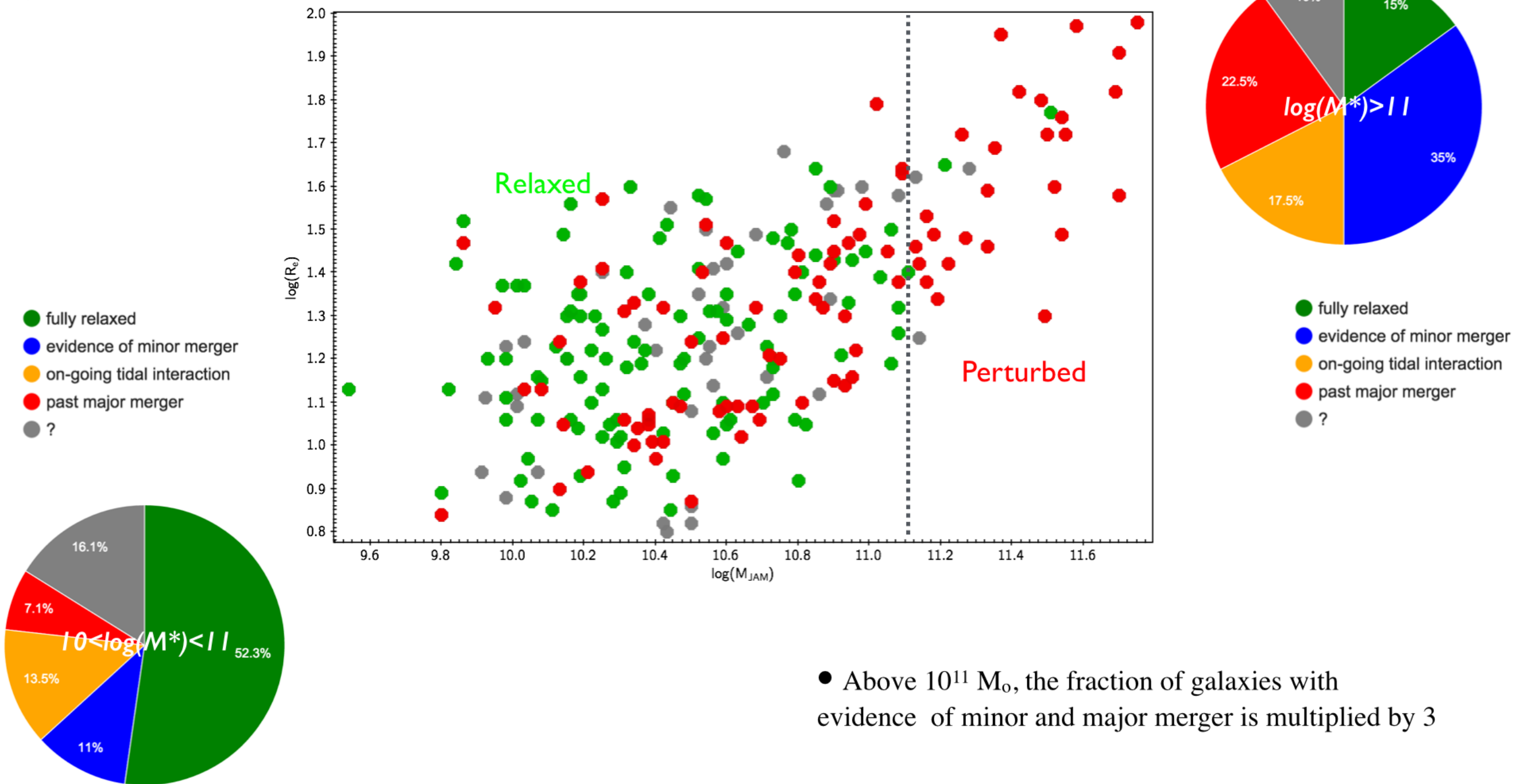
Statistics on morphological class based on fine structures  
to be compared with simulations (see Brisa's talk)







## ✓ Mass and Size



Statistics on morphological class based on fine structures



**Looking for extended halos**

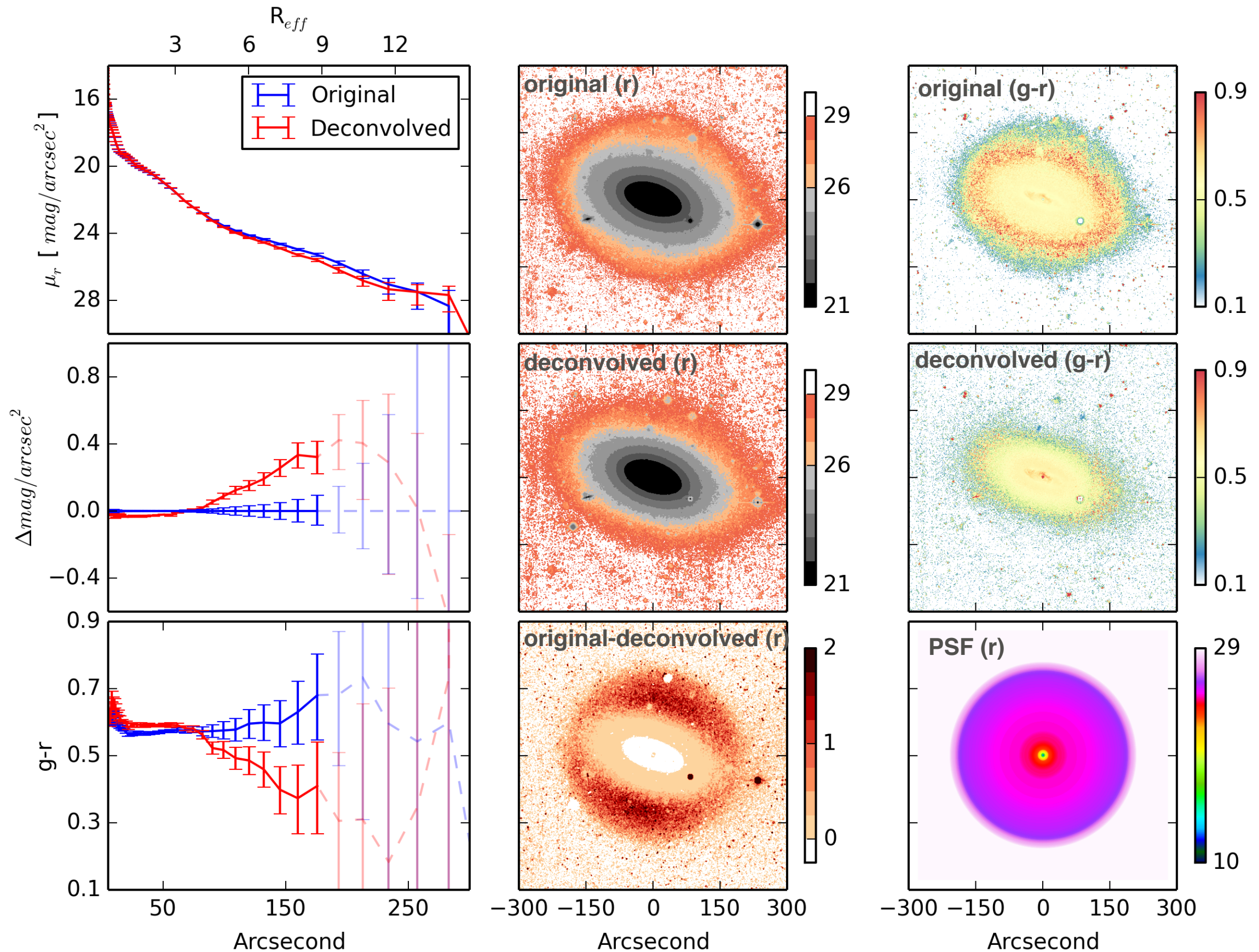


The forgotten role of  
NGC 7317

**Stephan's Quintet:reproducing the past mass assembly of the group**



### Issue 3: deconvolution required to get proper outer light and color profiles

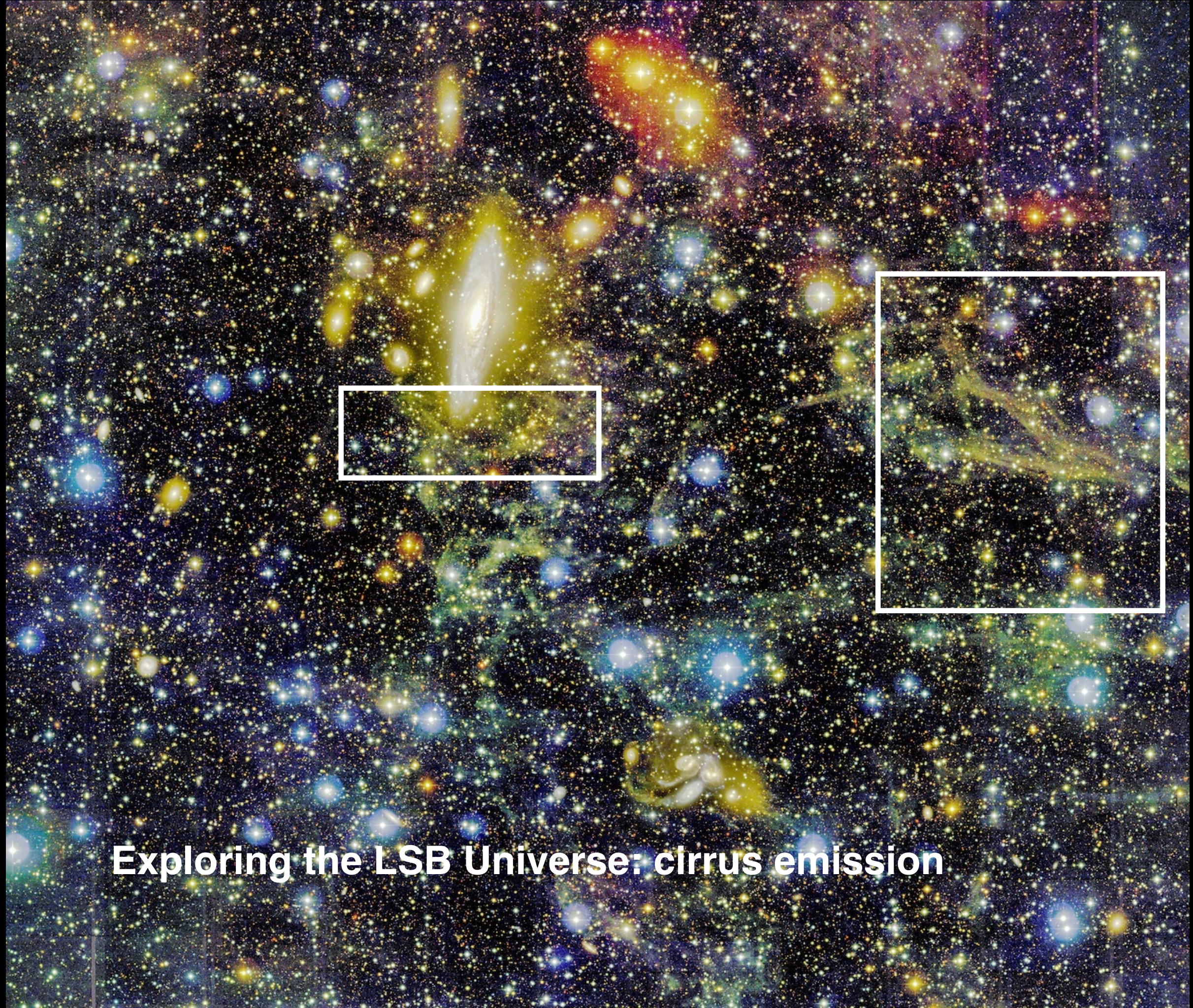






**NGC 7331 field of view with CFHT**





**Exploring the LSB Universe: cirrus emission**

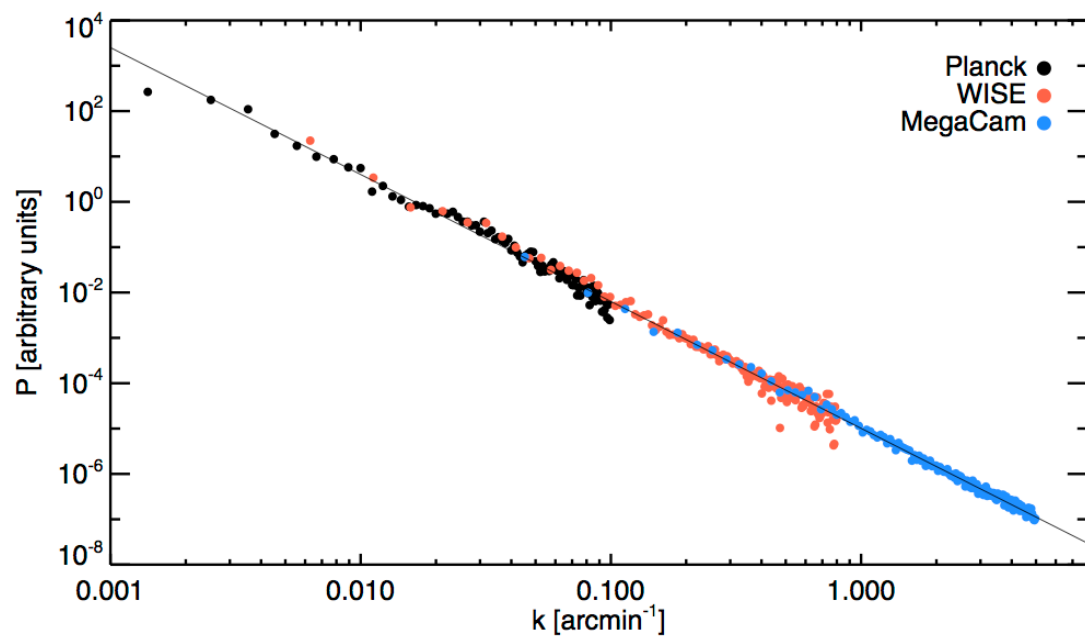
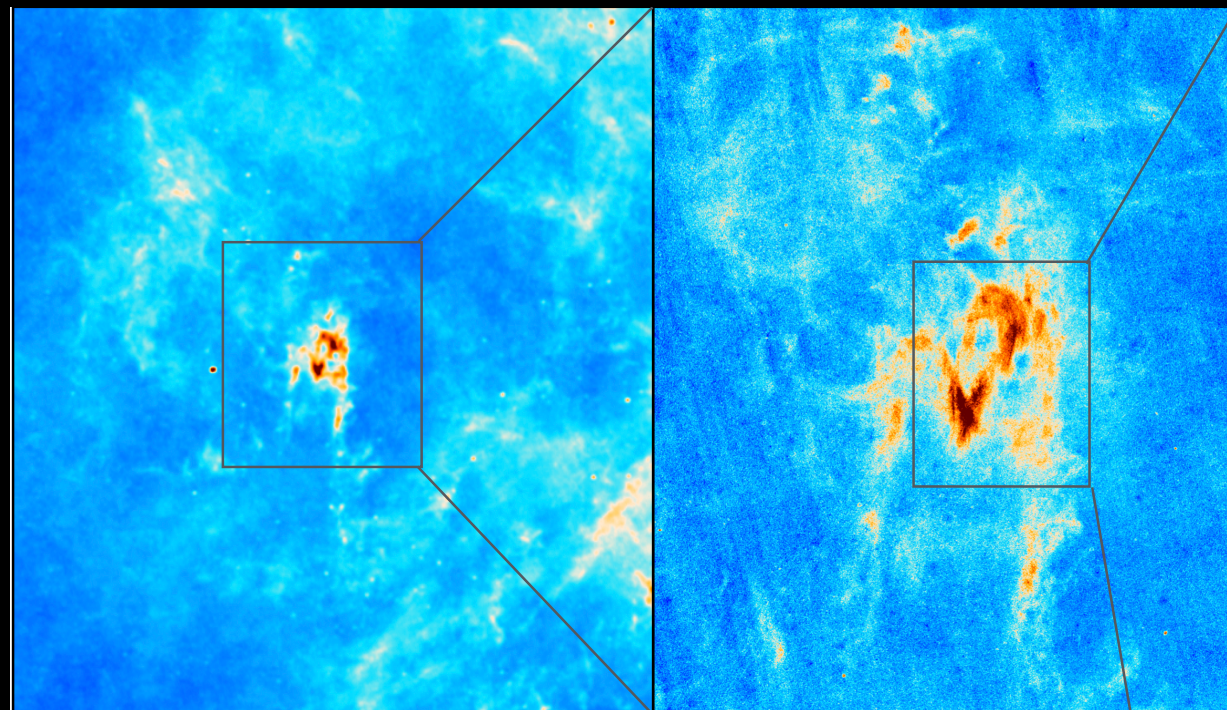


## Issue 4: cirrus

→ Study the **ISM** at very high spatial resolution with the scattered optical emission of nearby Galactic cirrus

Miville-Deschenes et al., 2016

*MATLAS*







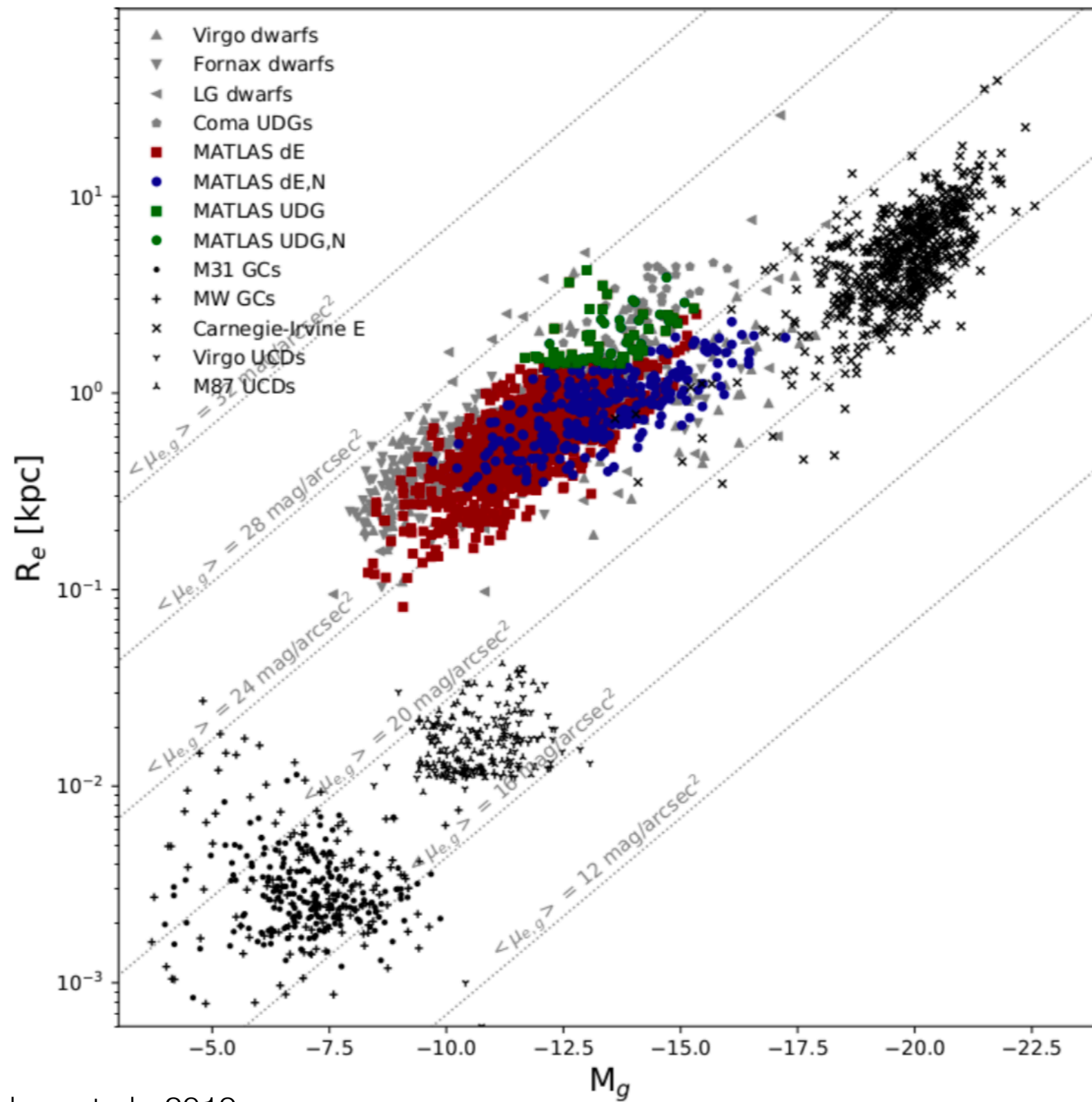
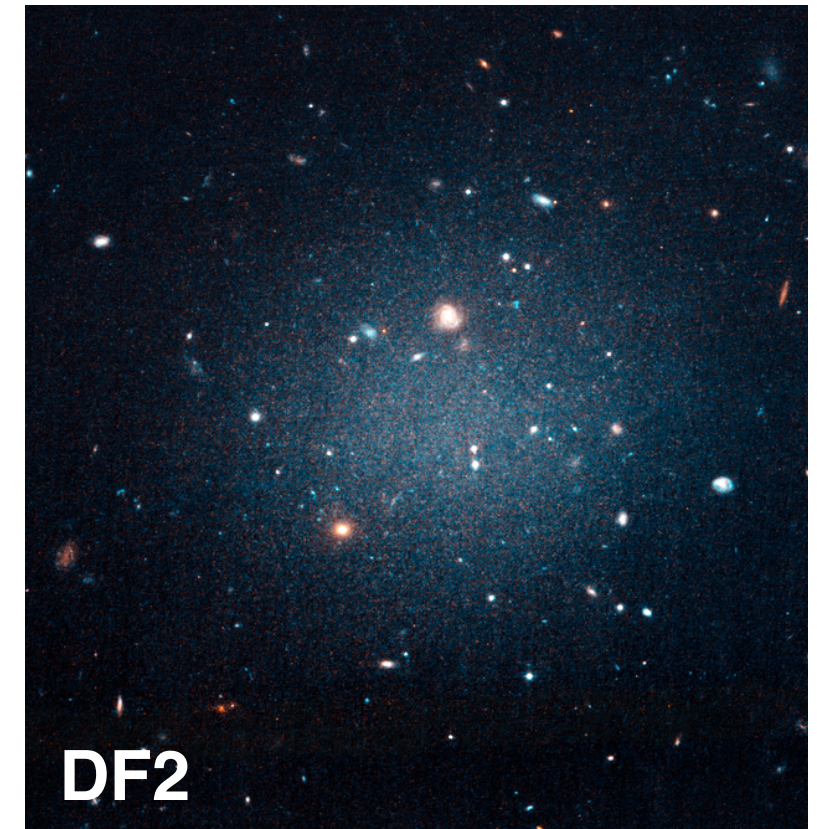
**Exploring the LSB Universe: dwarf satellites**

**In the quest of Ultra Diffuse Galaxies**

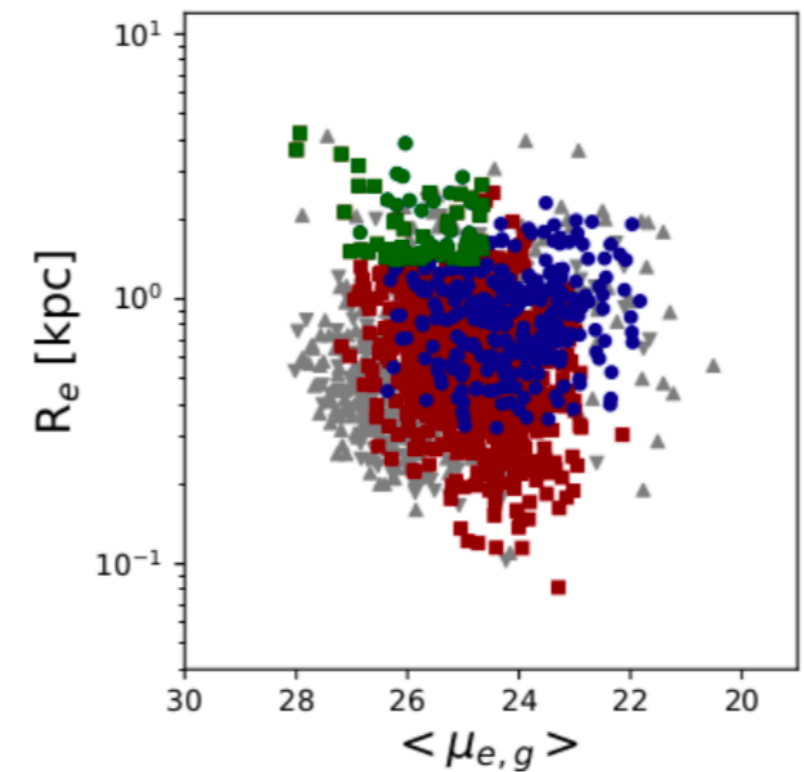


# Searching for Ultra Diffuse Galaxies

Van Dokkum et al., 2018



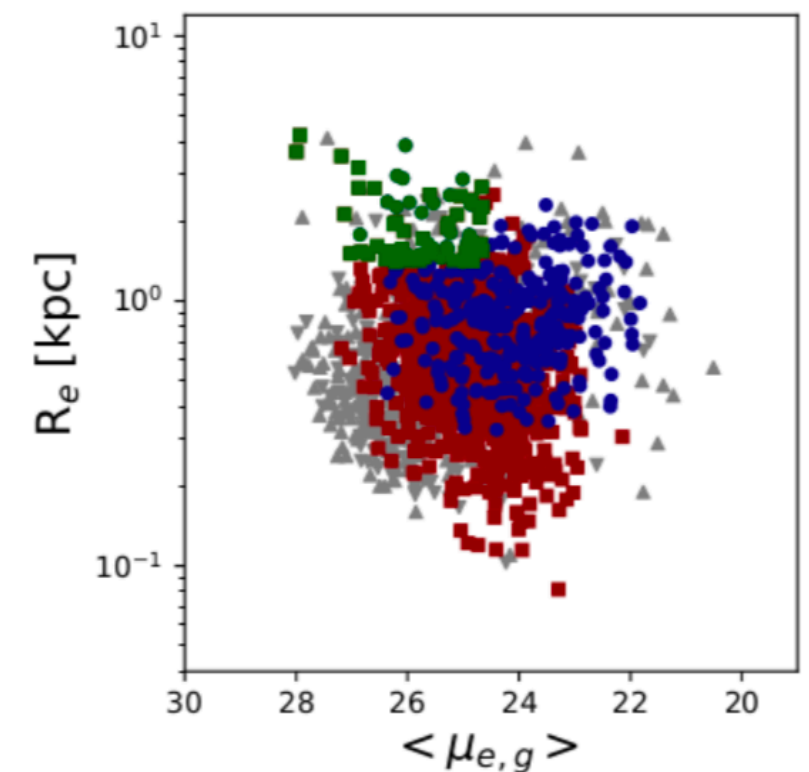
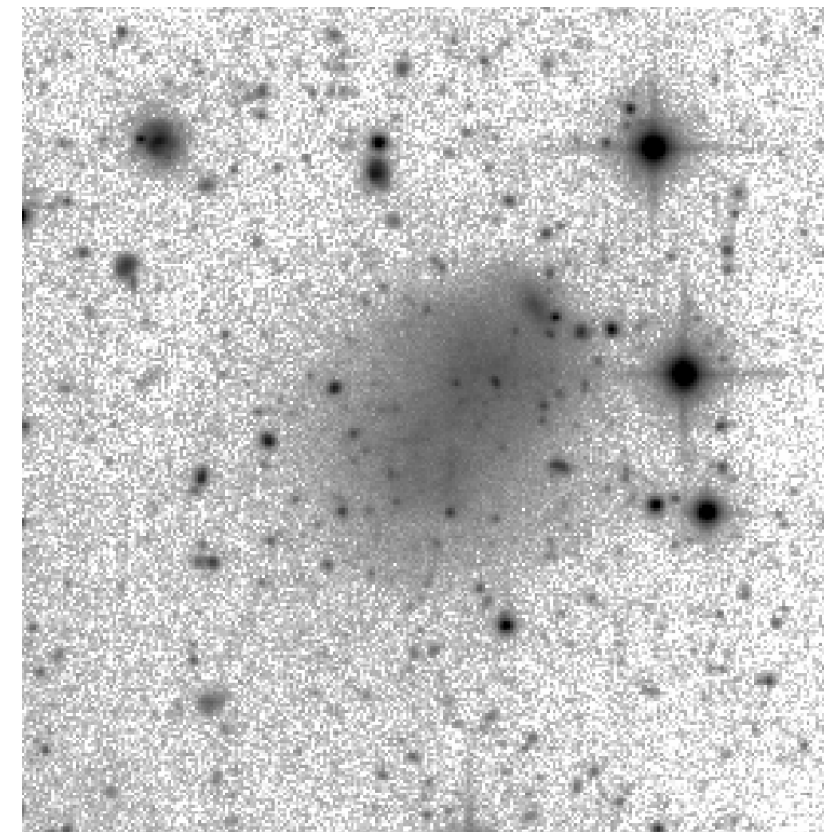
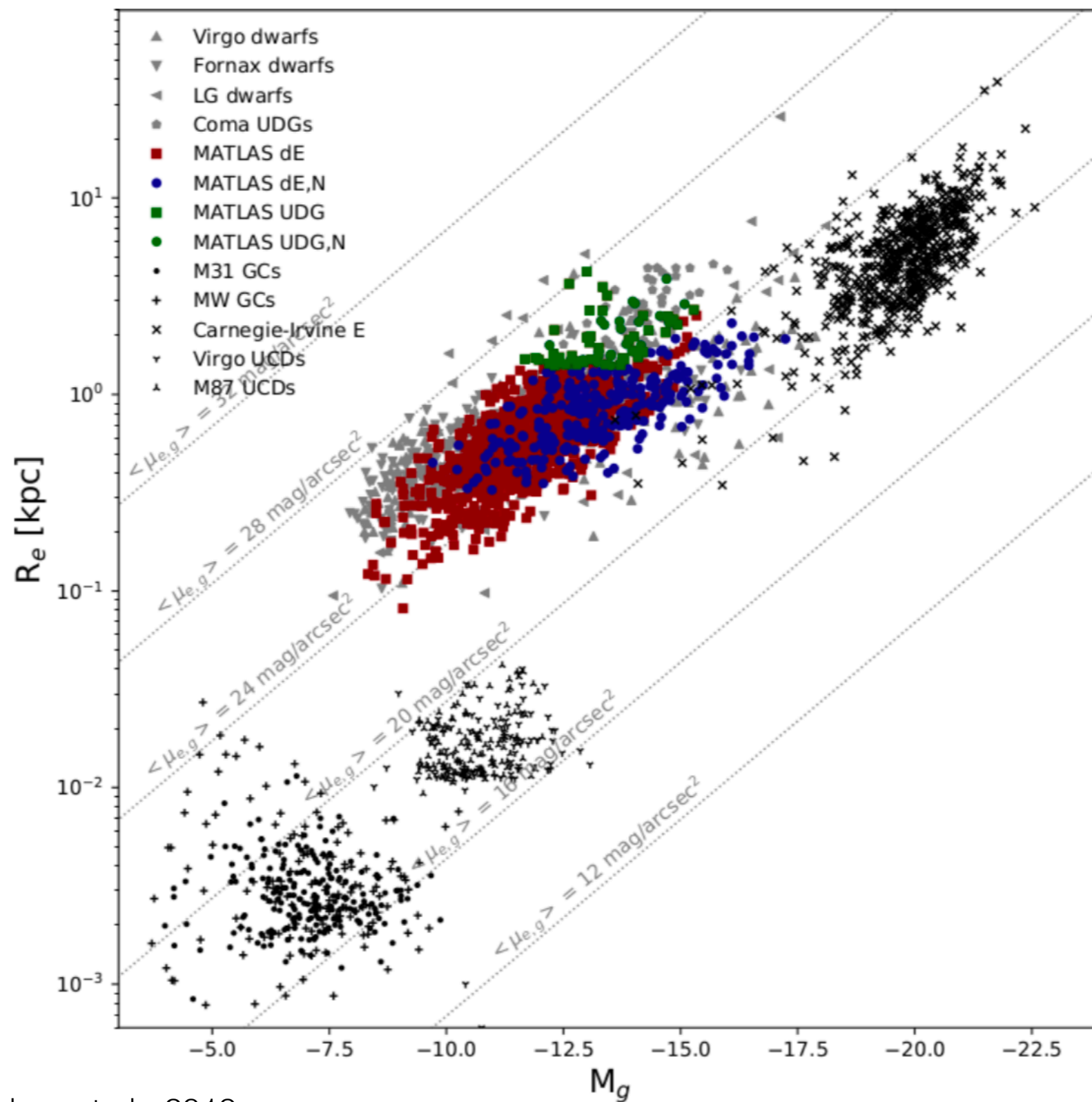
Habas et al., 2019





# Searching for **Ultra Diffuse Galaxies**

Some with a GC excess

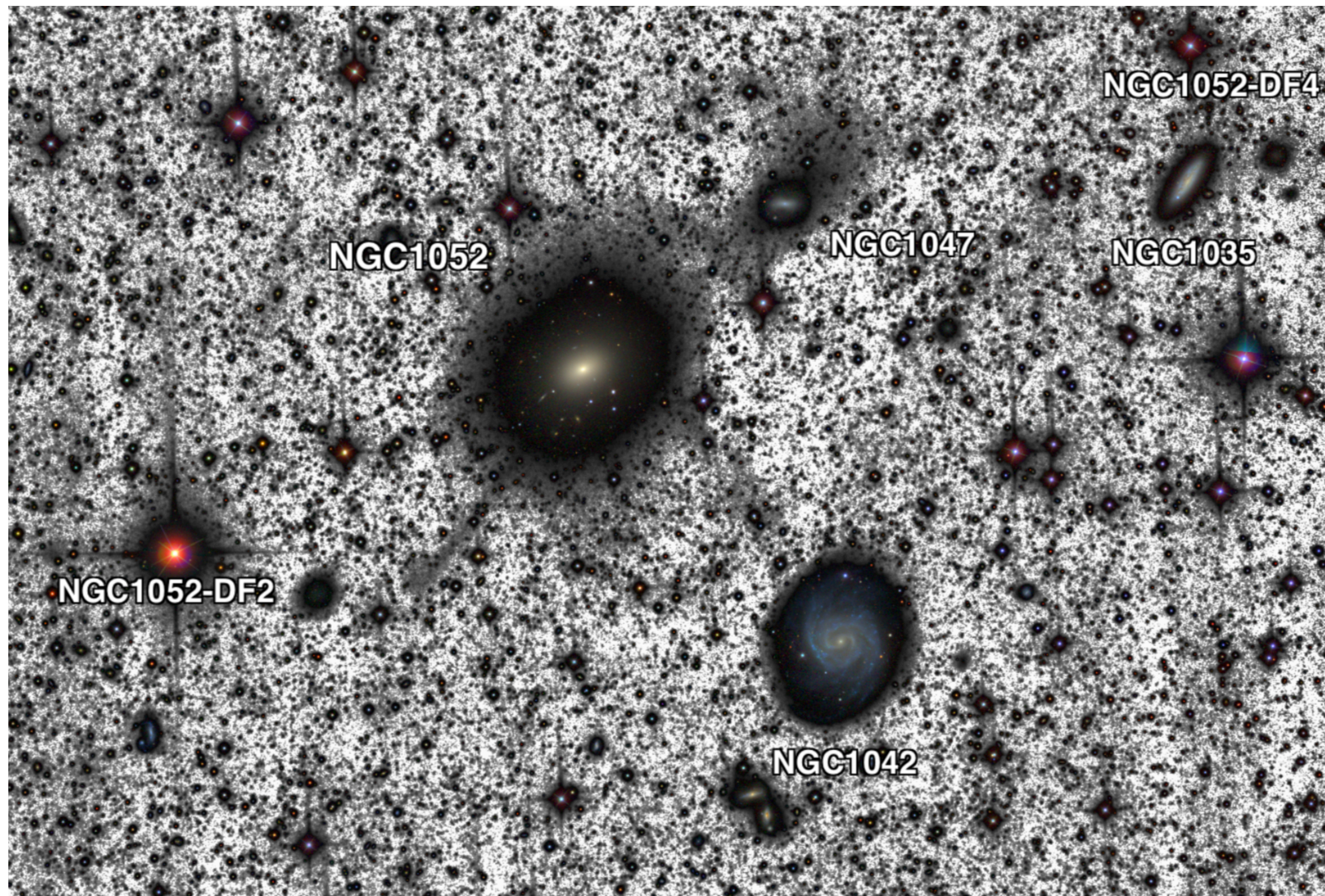


Habas et al., 2019

MUSE follow-up observations to come to infer the DM content

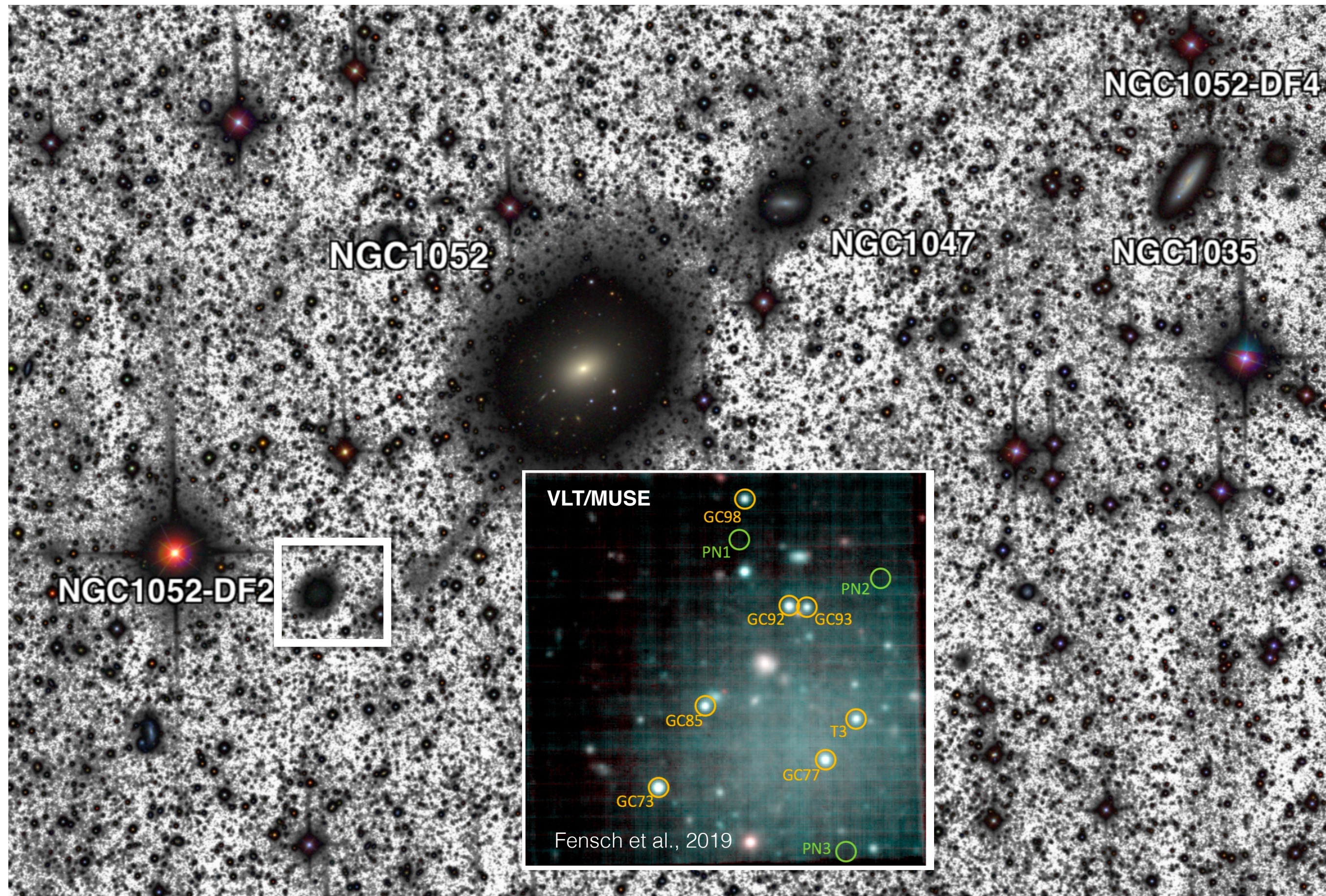


# The rich environment of the infamous UDG NGC 1052 DF2



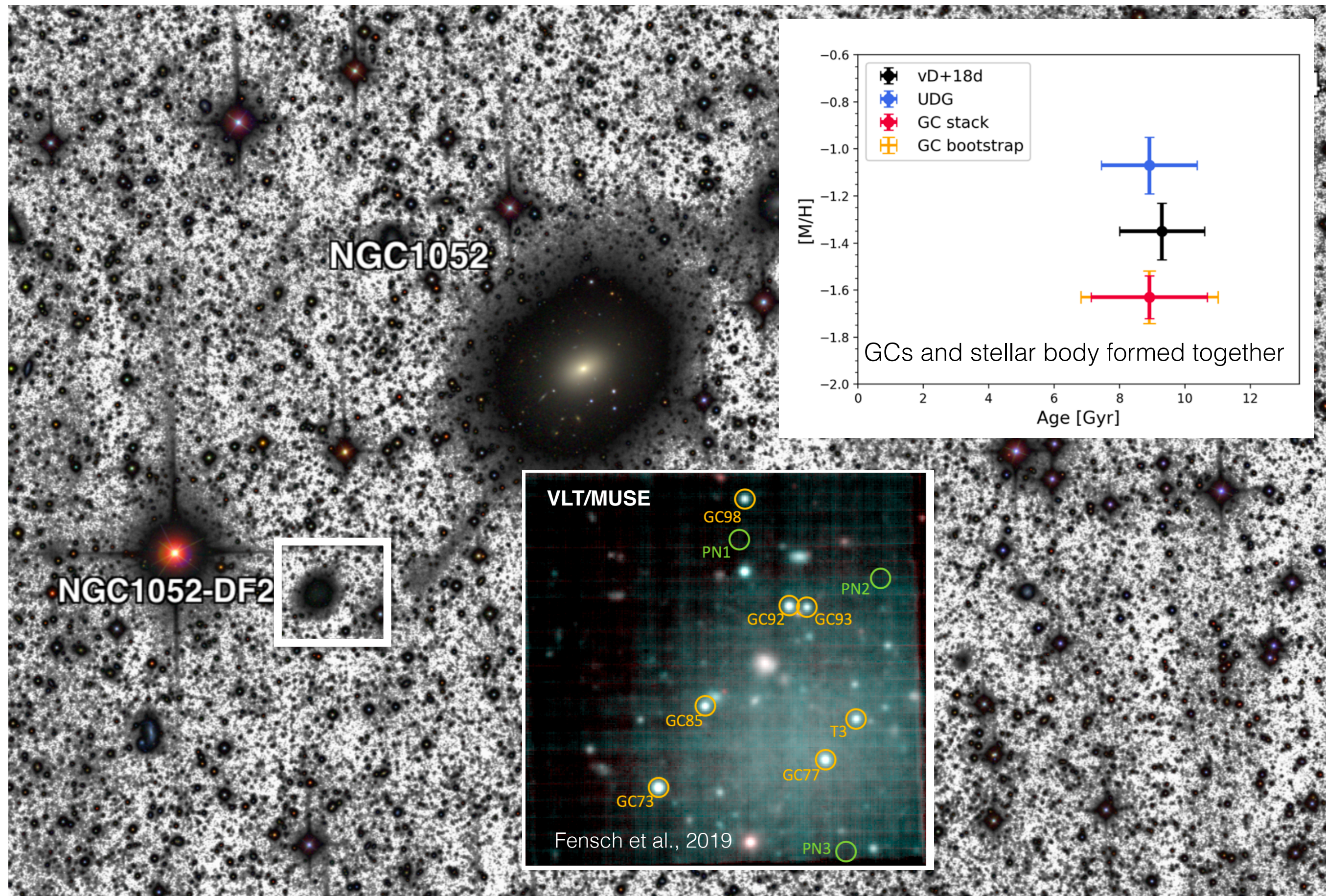


# NGC 1052 DF2: DM poor or rich? Having or not an excess of GCs?





# NGC 1052 DF2: Lack? of DM, environment with tidal features, GC rich?





# An invitation to explore the LSB Universe

- Past mass assembly reconstruction studying LSB features  
*Critical mass above which tidal features become prominent (MATLAS survey)*
- Limitations and opportunities: Galactic cirrus
- Exploiting the CFHT large foc and IQ: satellites, UDGs/TDGs and GCs
- Rich prospect: CFIS, LSST, Euclid and on-going deep surveys (HSC, Dragonfly, J.Rich, etc.)