Small fuzzy satellites in the Local Universe:
testing dark matter and galaxy formation with low surface brightness dwarfs

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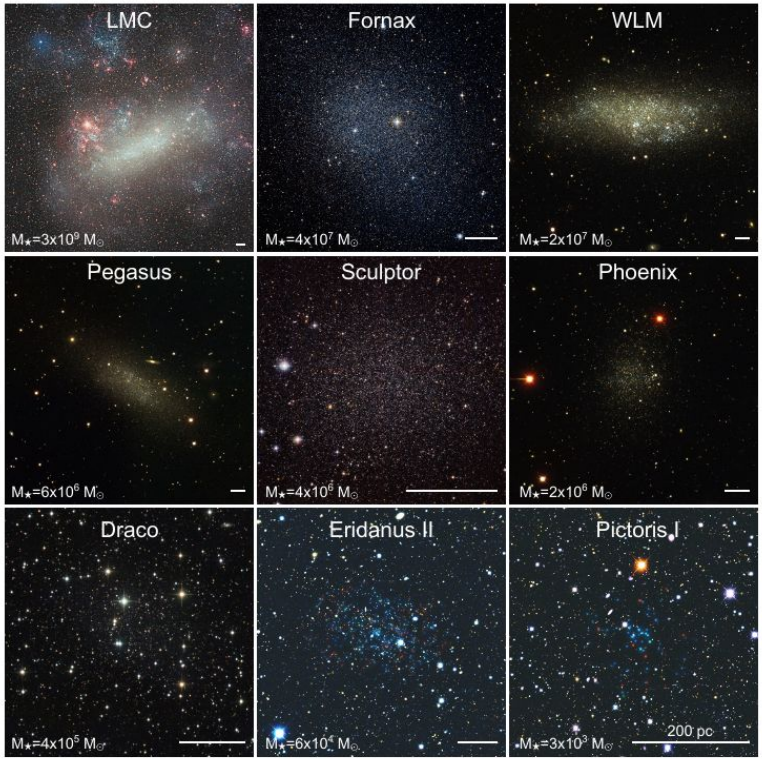
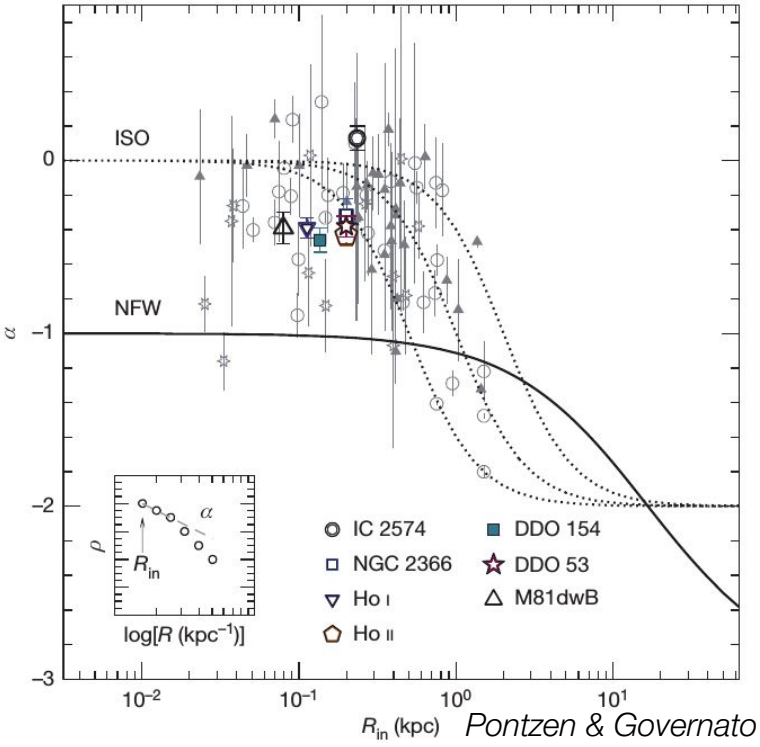
Instituto de Física - UFRGS

Small-scales challenges to the ΛCDM paradigm



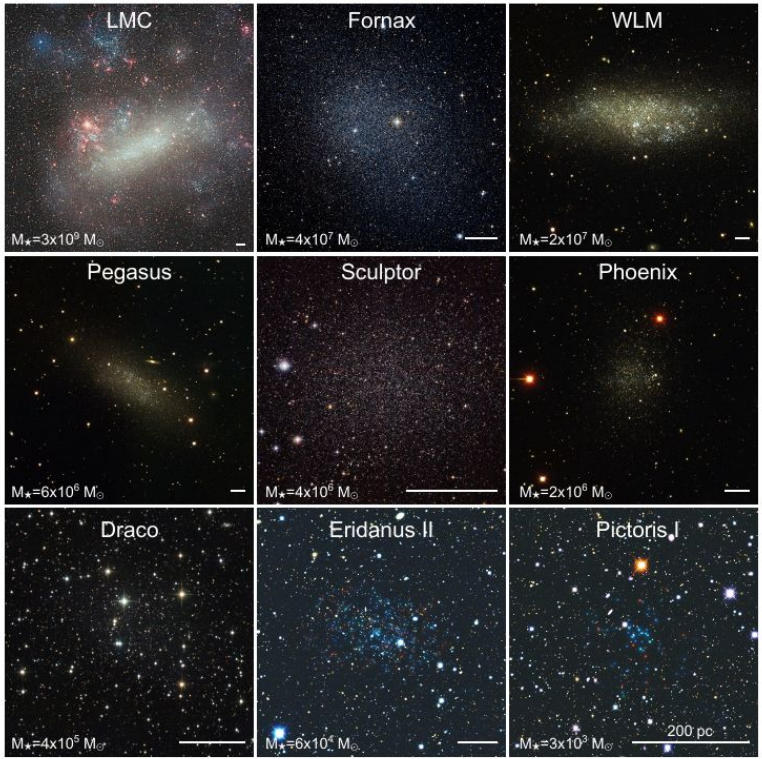
Bullock & Boylan-Kolchin (2017)

Constant-density cores of dark matter in dwarf galaxies

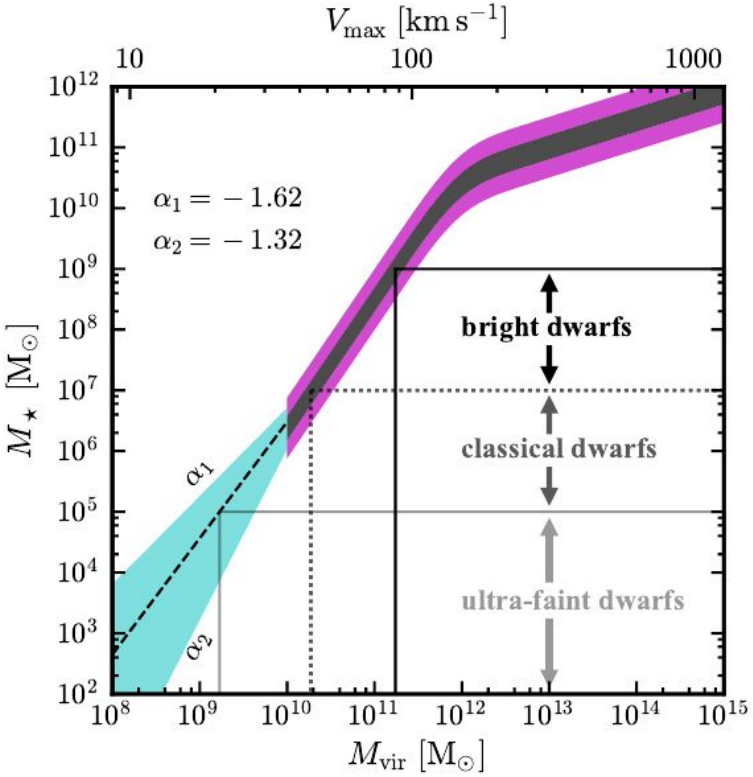


Pontzen & Governato (2014)

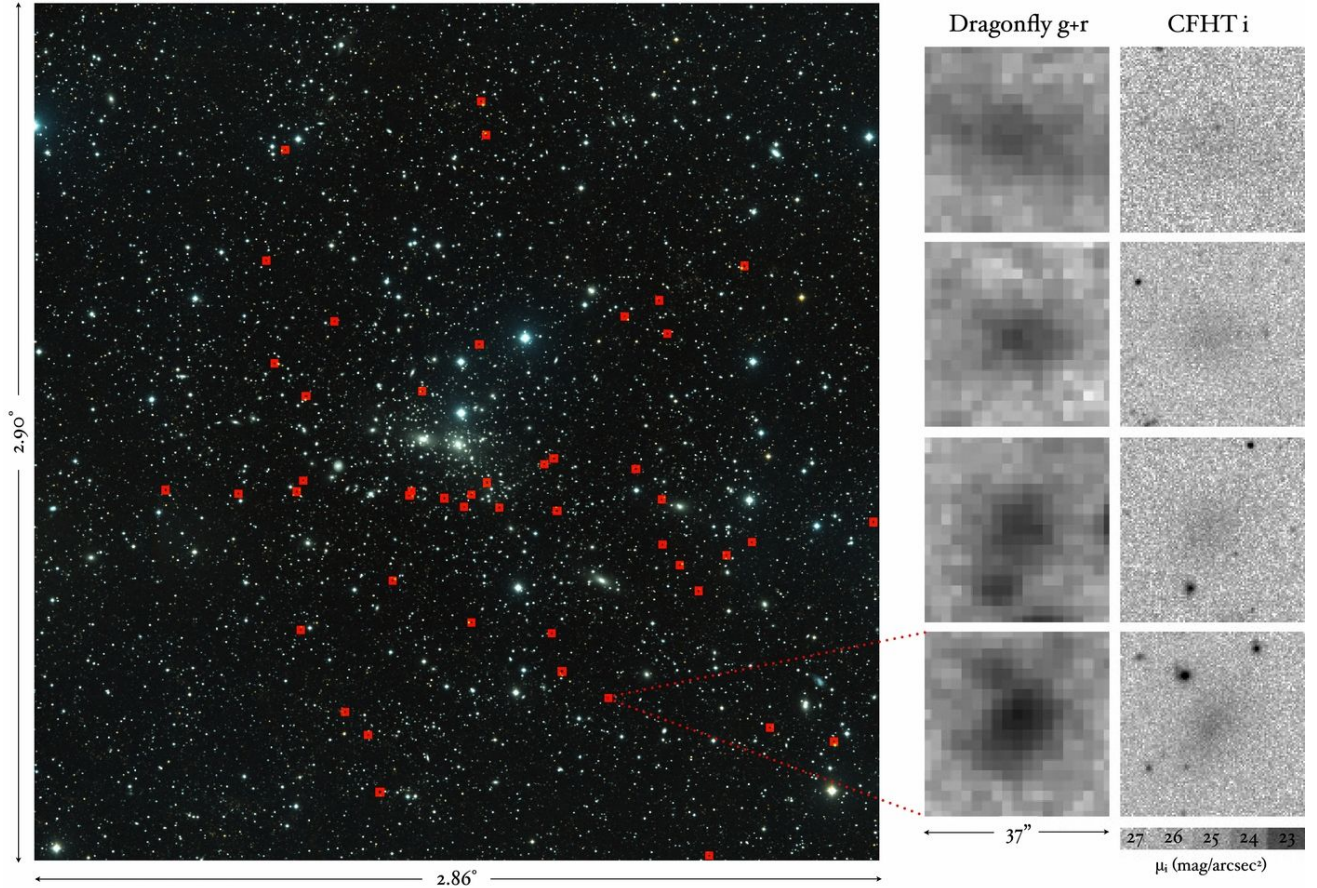
Small-scales challenges to the ΛCDM paradigm



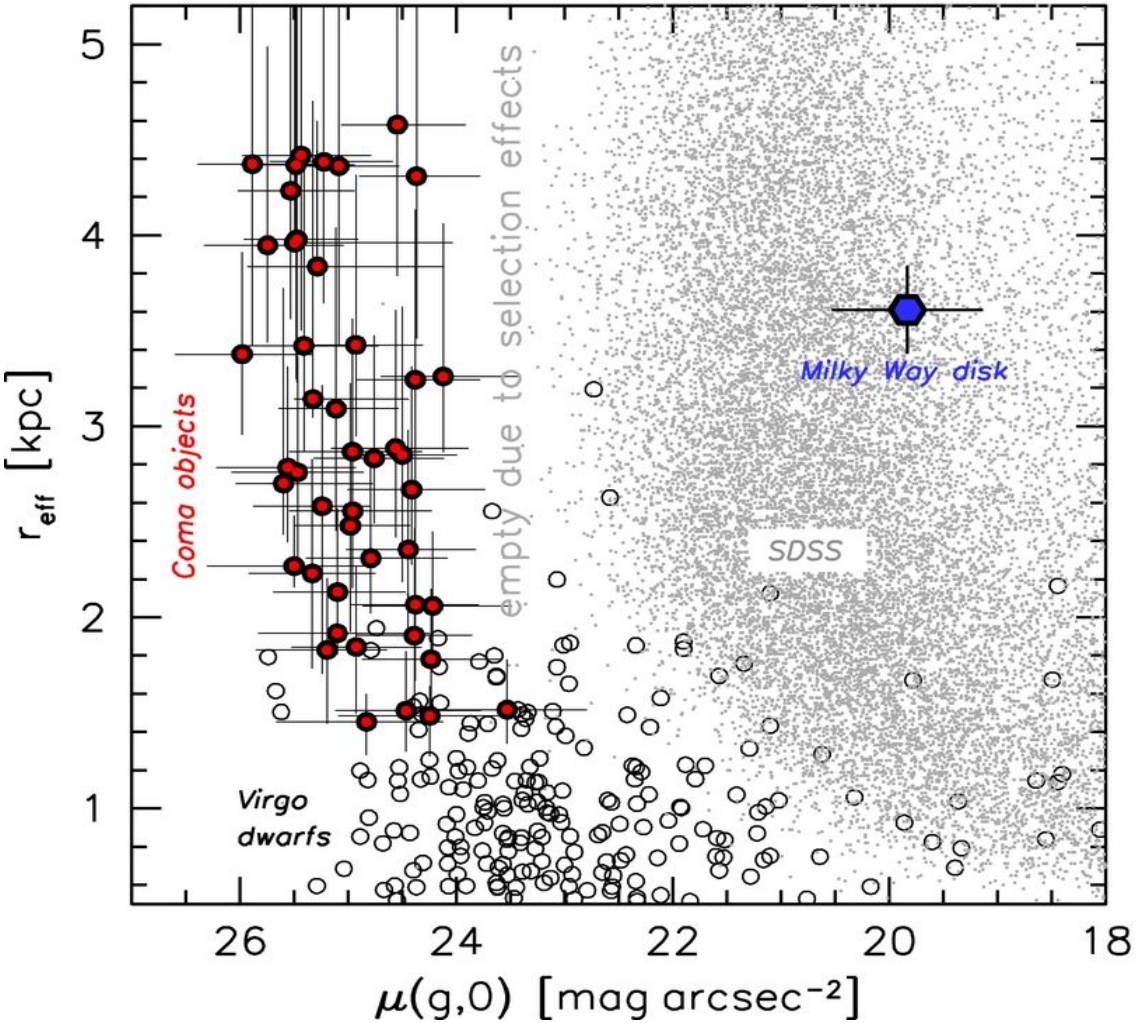
Bullock & Boylan-Kolchin (2017)



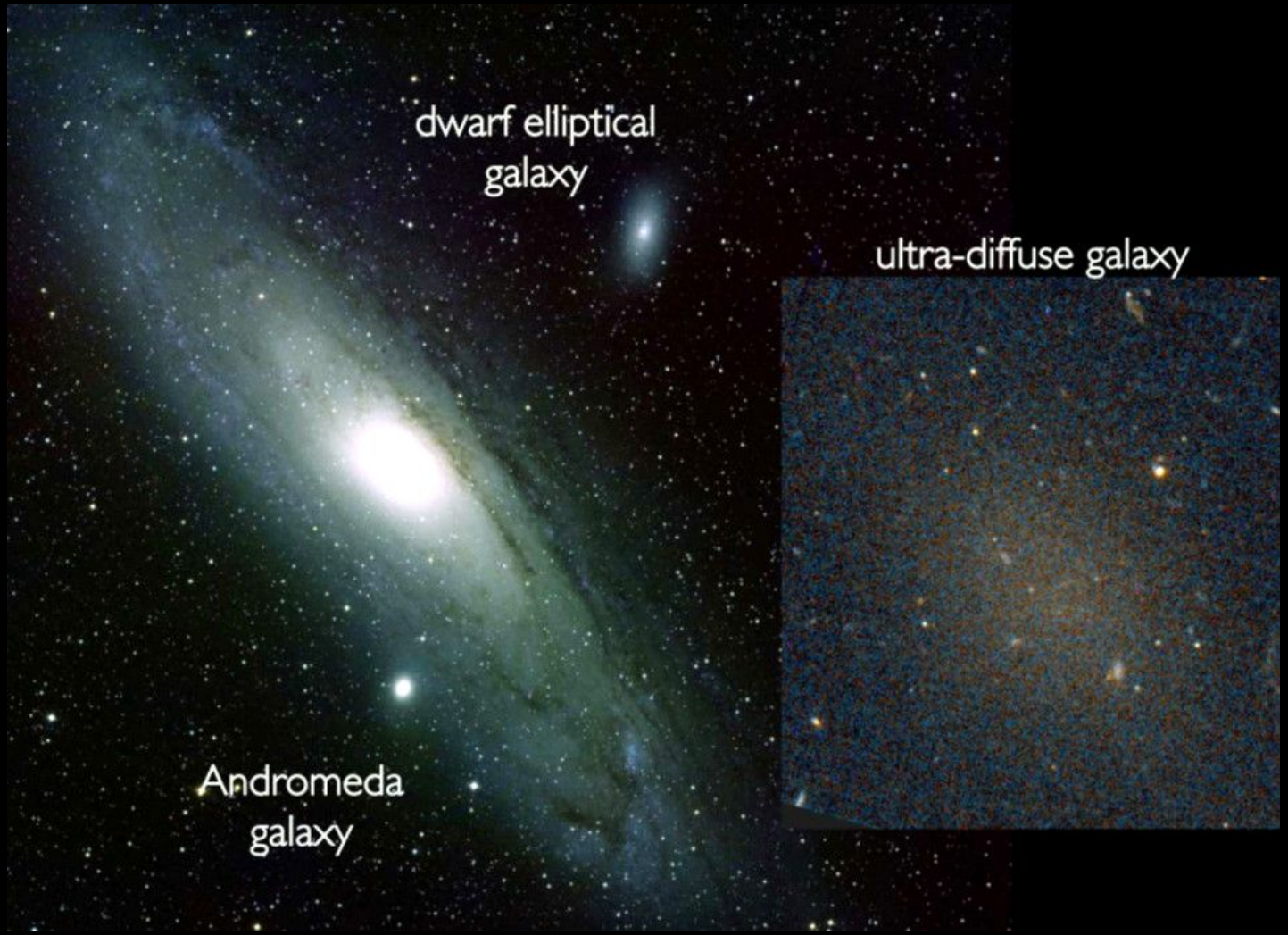
Ultra-diffuse galaxies (UDGs) found in Coma



van Dokkum et al. (2015)



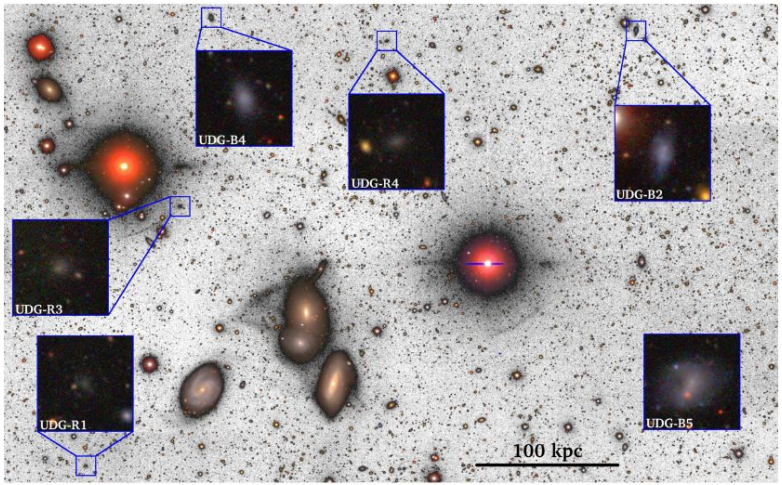
van Dokkum et al. (2015)


dwarf elliptical
galaxy
ultra-diffuse galaxy
Andromeda
galaxy

Are UDG found in other environments?

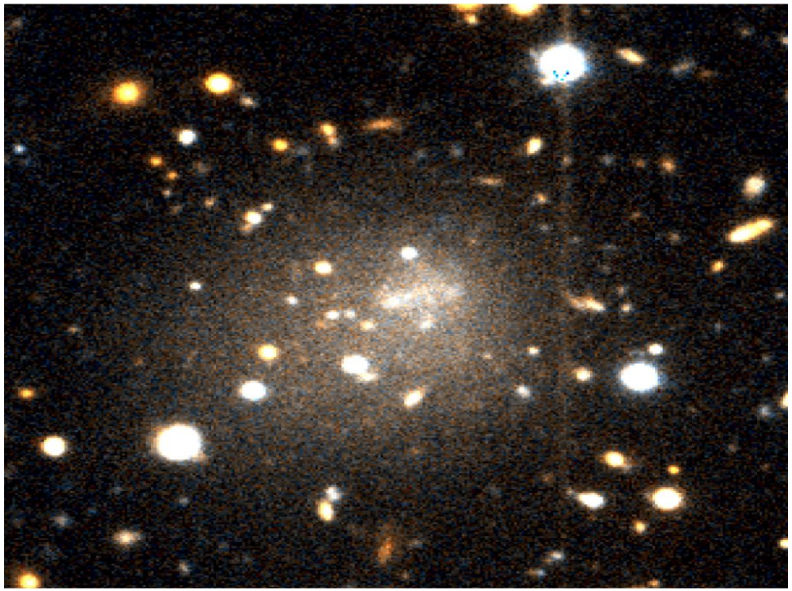
UDGs in Fornax, Virgo and other low-z clusters

Mihos et al. (2015), van der Burg et al. (2016), Mancera Piña et al. (2018)



UDGs in galaxy groups HCG07

Román & Trujillo (2017)



DGSAT I (isolated)

Martinez-Delgado et al. (2016)

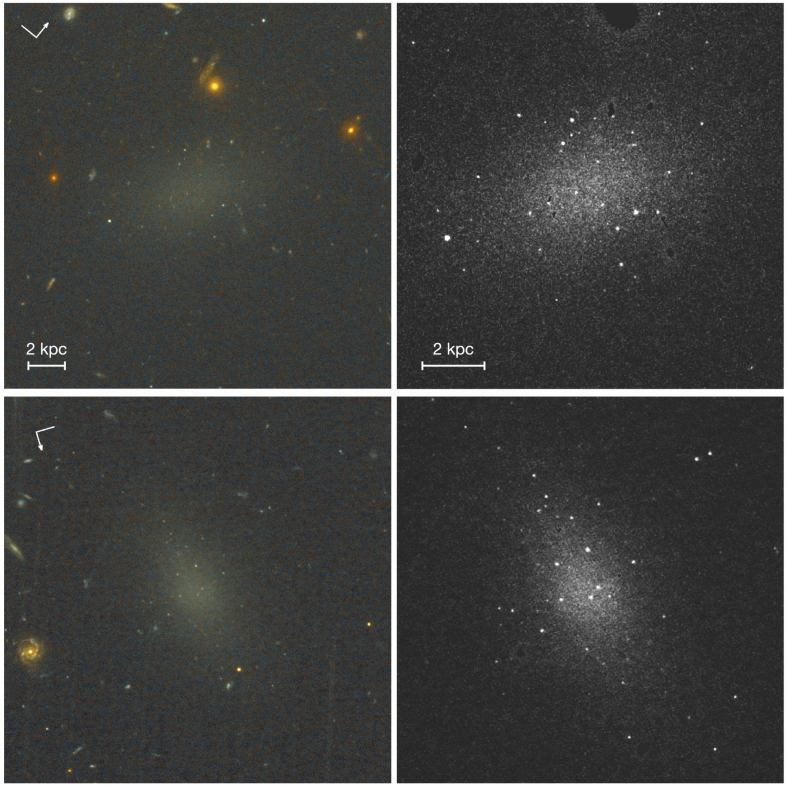
How do they form?

- Are they failed L* galaxies?

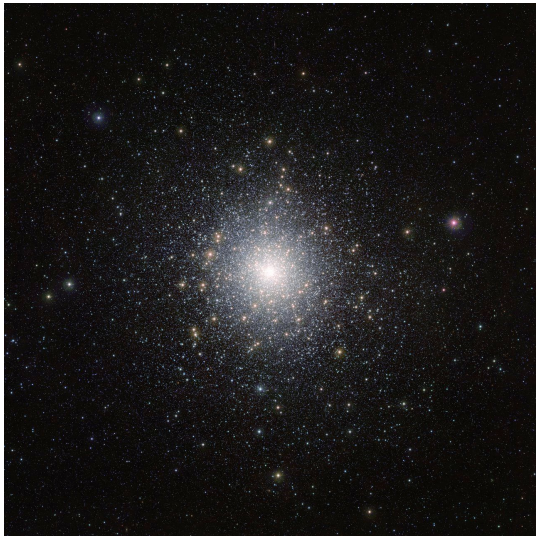
How do they form?

- Are they failed L* galaxies?
- Do they live in dwarf halos?

UDGs can have a lot of globular clusters (GCs)



van Dokkum et al. (2017)

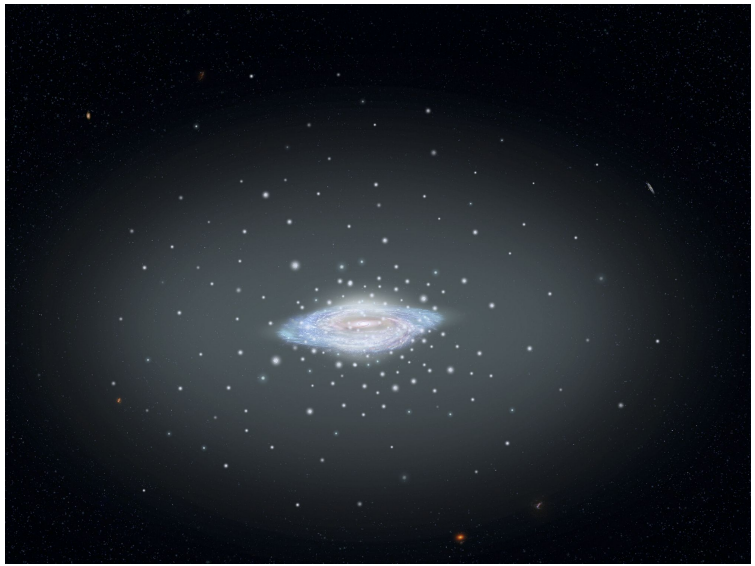


Compact and luminous stellar objects

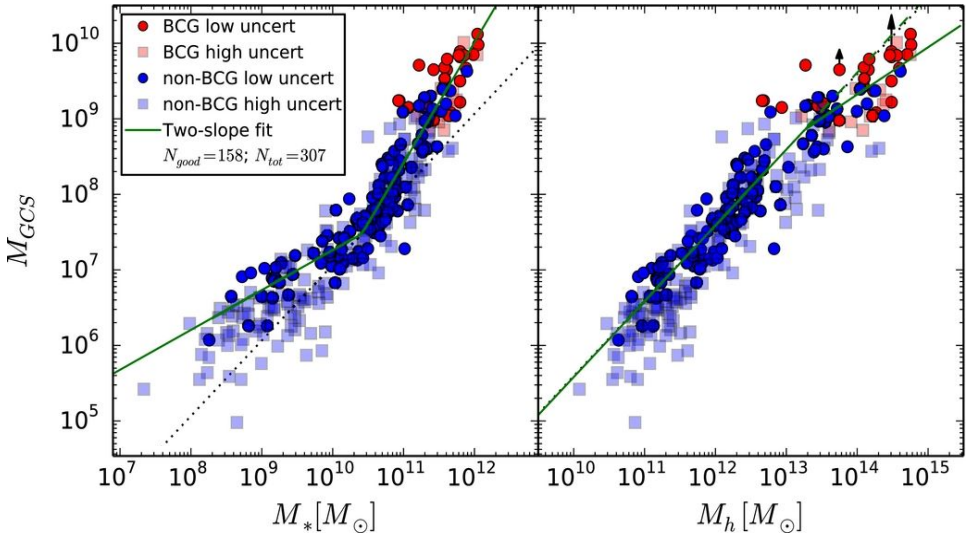
Stellar mass: ~10^4-10^6 M_{sun}

GCs are useful mass tracers

Extended kinematical tracers of host galaxies

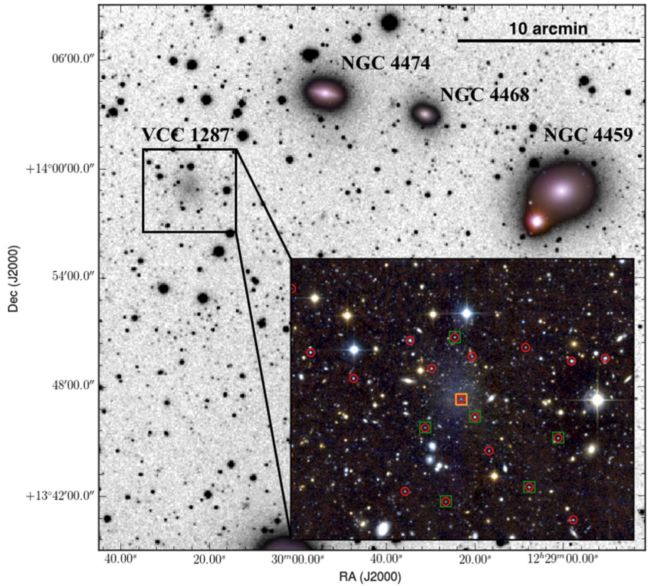


Mass/number of GCs scales with halo mass

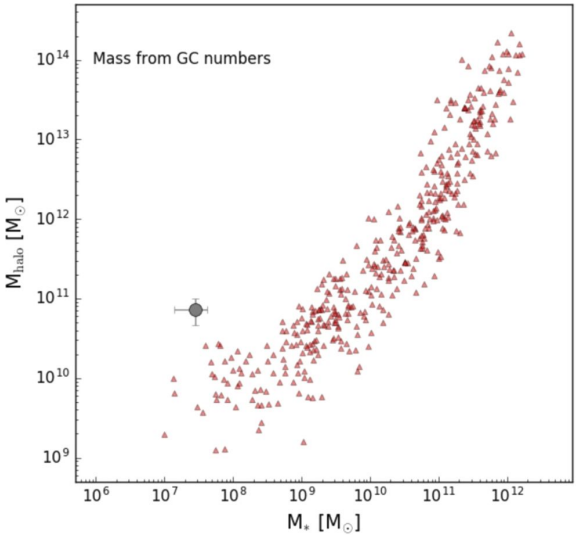


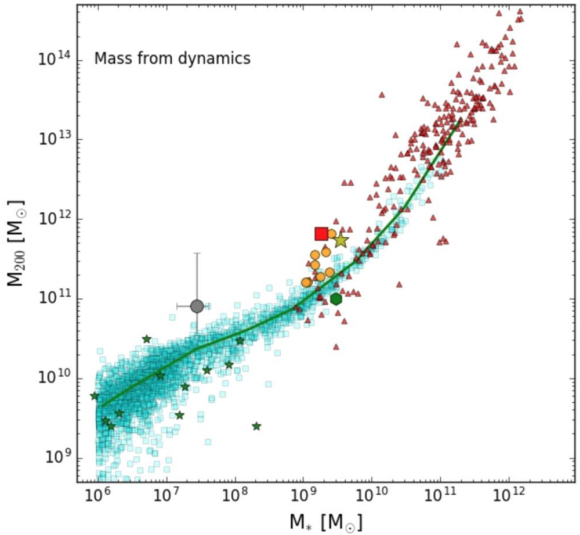
Hudson et al. (2014)

Measuring total mass of UDGs



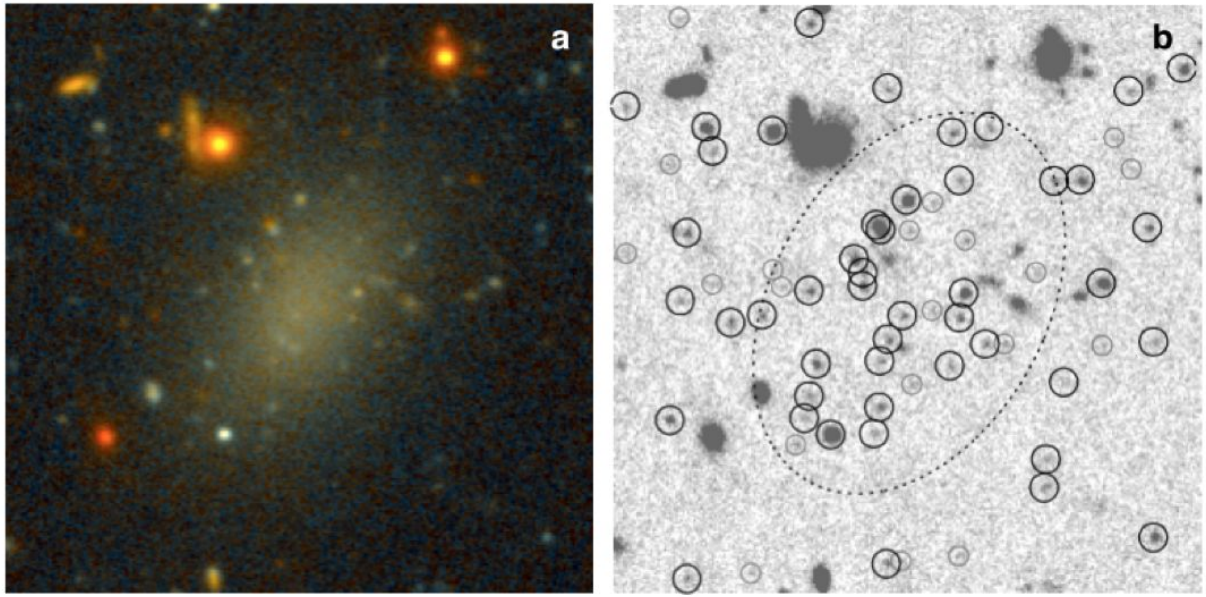
Beasley et al. (2016 a,b)





Globular clusters (GCs) indicate that masses of UDGs are typical of dwarfs

Measuring total mass of UDGs



DF44

~100 GCs

stellar kinematics
σ = 47 km/s

$M_{total} \sim 10^{12} M_{\odot}$

UDGs are likely “failed” galaxies, with the sizes, dark matter content, and GC systems of much more luminous objects.

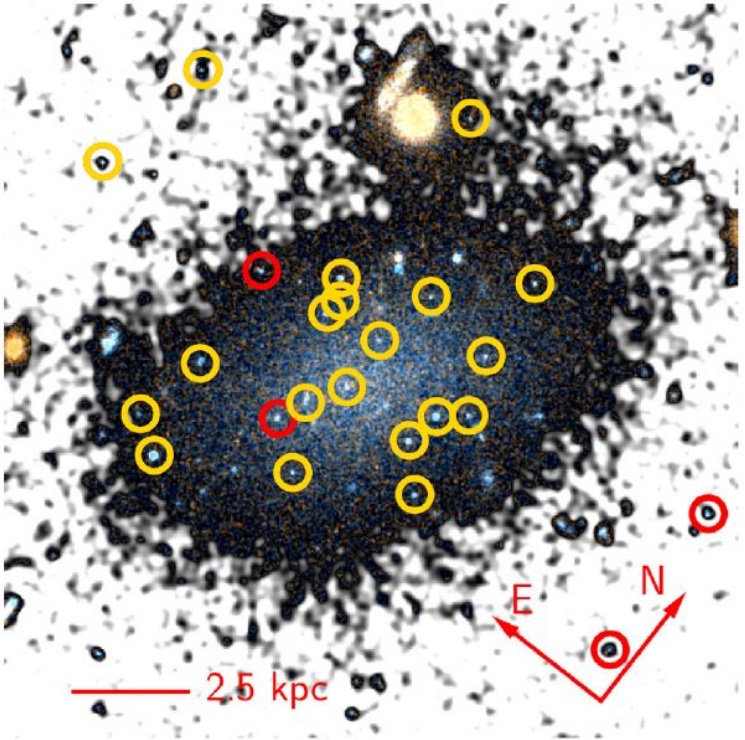
van Dokkum et al. (2016)

Measuring total mass of UDGs

~18 GCs

$M_{halo} \sim 10^{11} M_{\odot}$

The number of globular clusters around the DF44 is as expected for dwarf galaxies



Saifollahi et al. (2020)

How do they form?

- Are they failed L* galaxies?

- Do they live in dwarf halos?
  - High spin halos
    - *Amorisco & Loeb (2016)*
    - However, no evidence of rotation in UDGs (van Dokkum et al. 2019)

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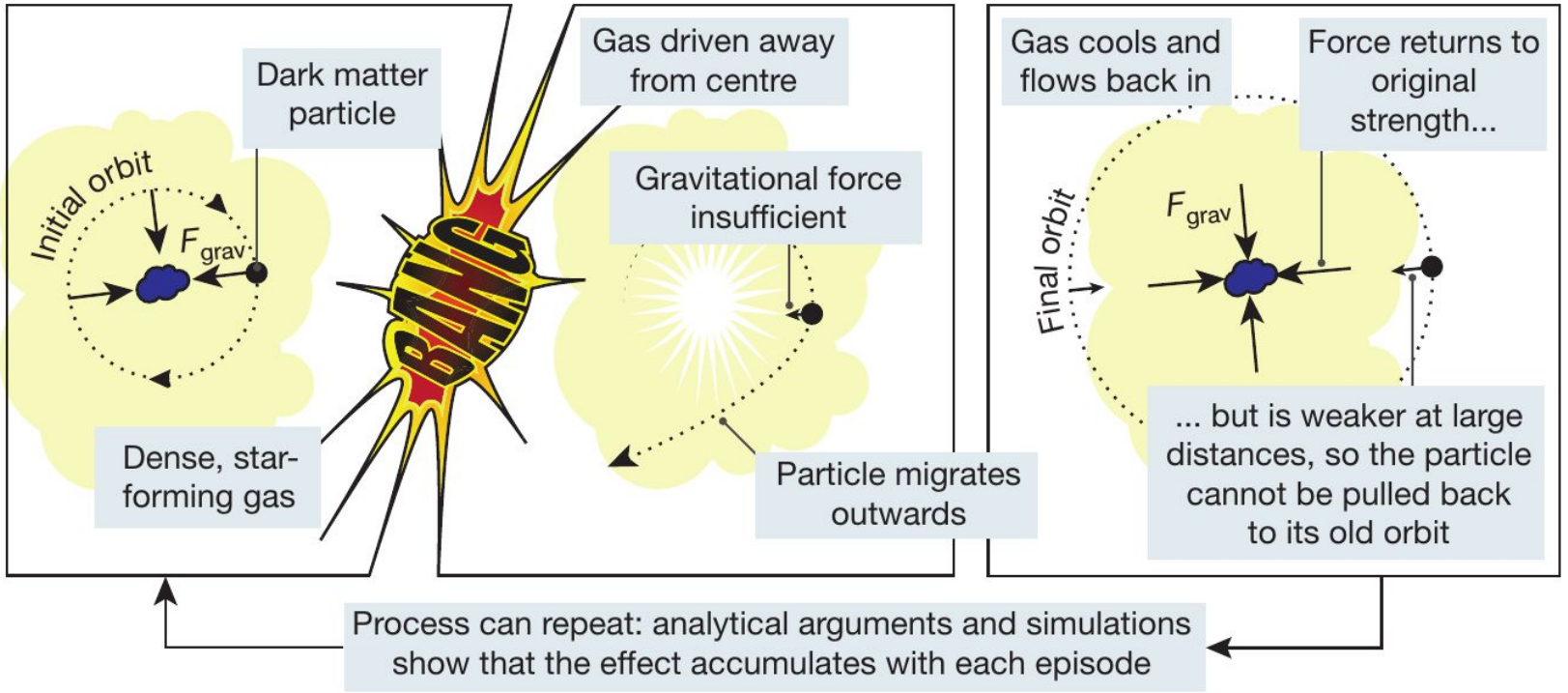
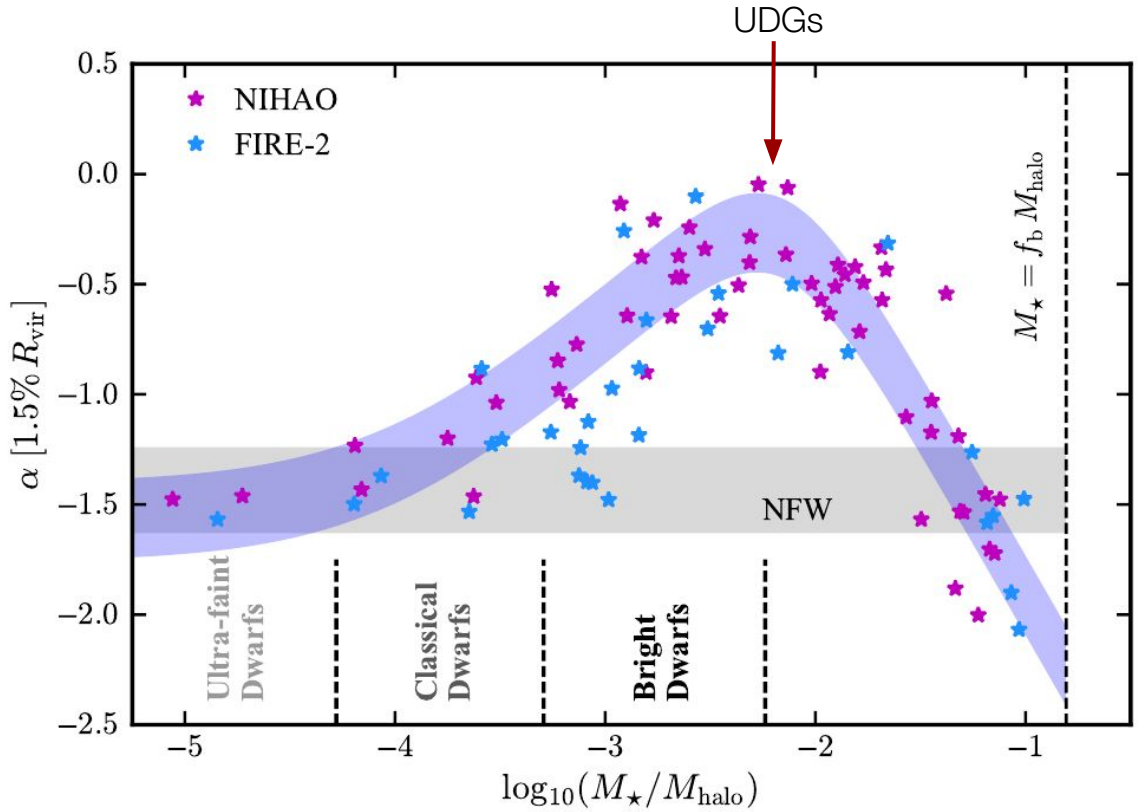
  - Feedback-driven expansion

Formation by feedback-driven outflows



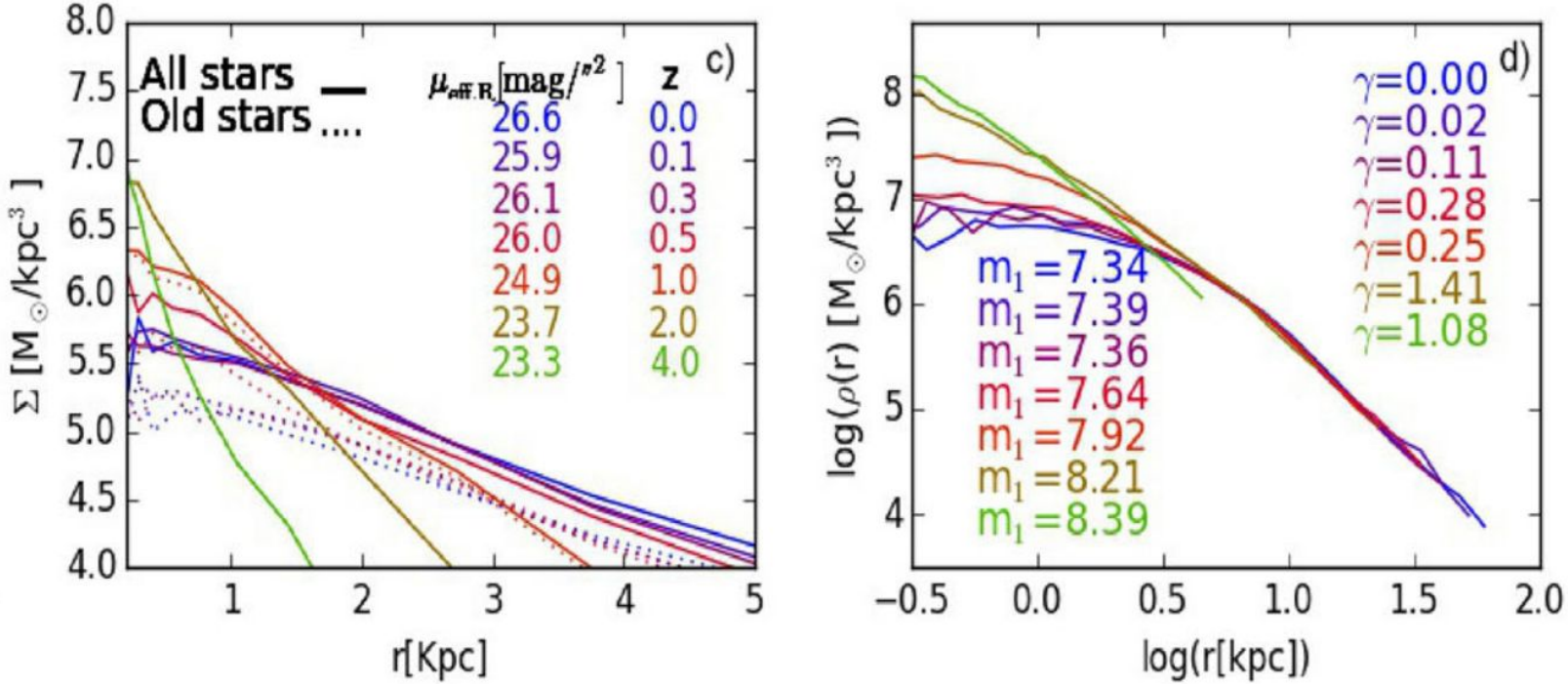
Pontzen & Governato (2014)

In simulations core formation is mass dependent



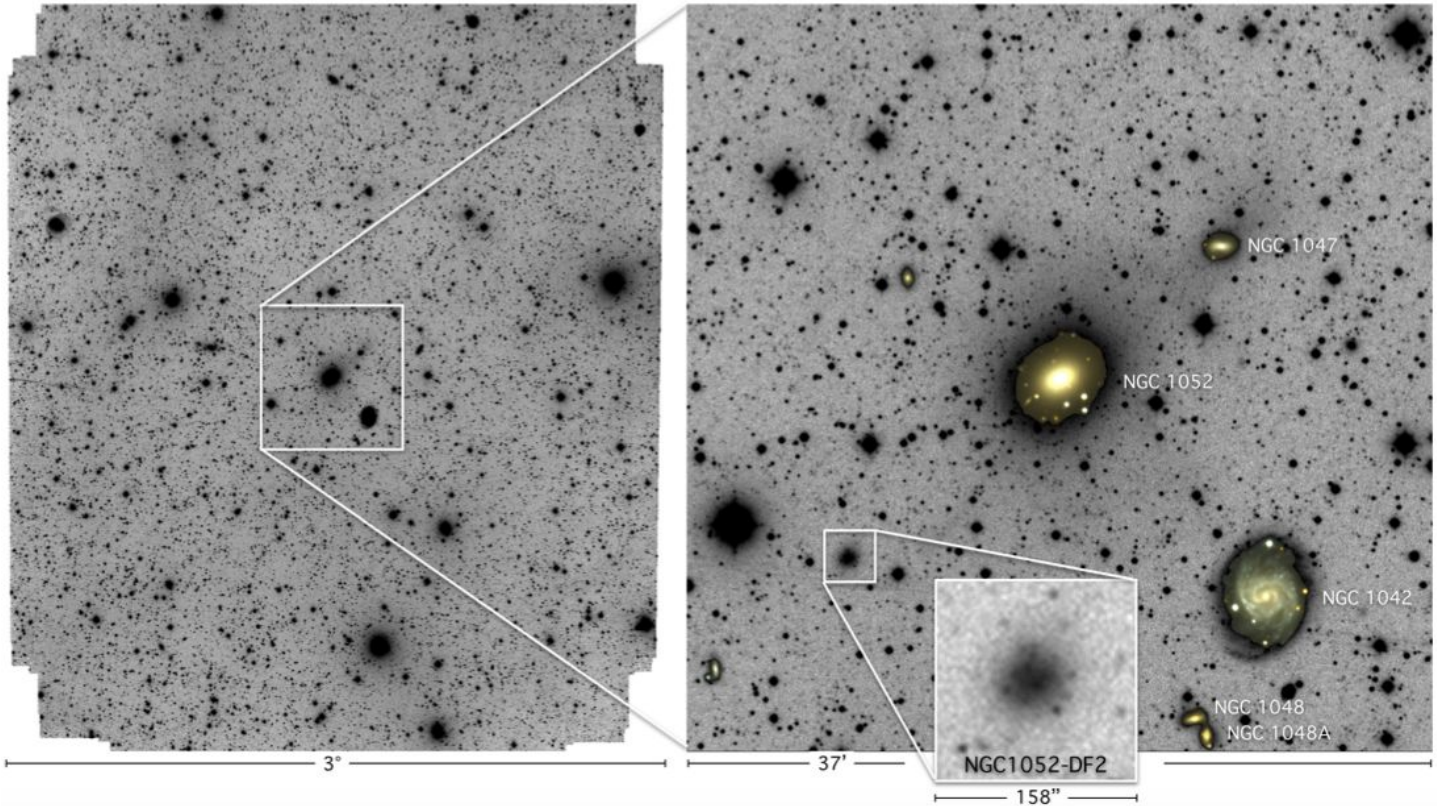
Bullock & Boylan-Kolchin (2017)

Formation of central dark matter core in UDGs by outflows



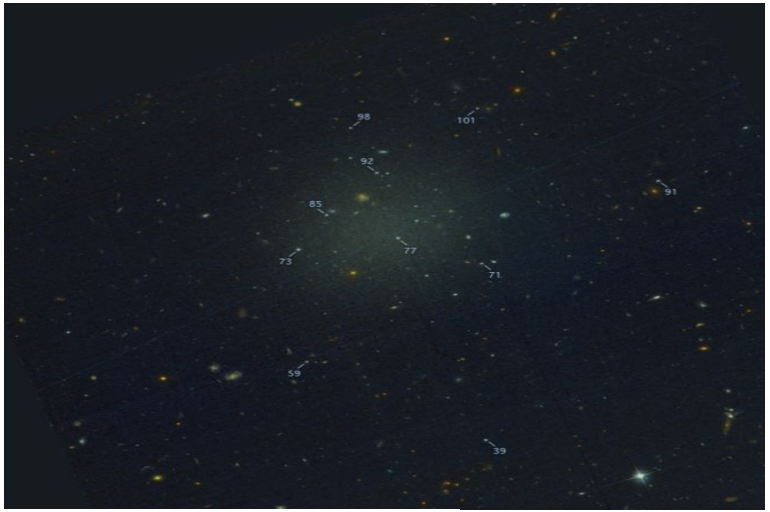
Di Cintio et al. (2017)

A galaxy missing dark matter?

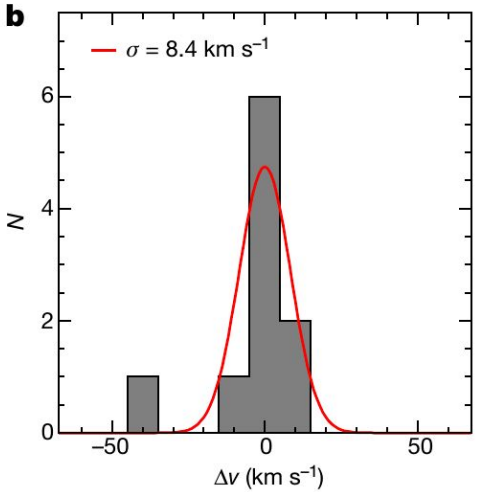


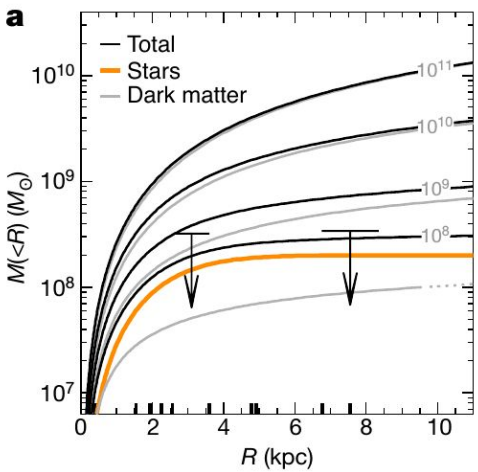
van Dokkum et al. (2018)

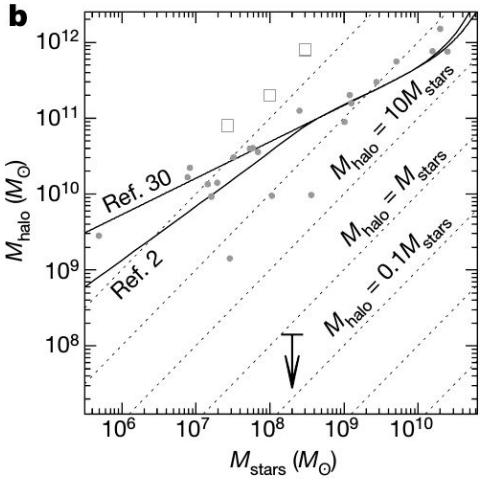
NGC1052-DF2: galaxy with too little dark matter



velocity dispersion of associated GCs



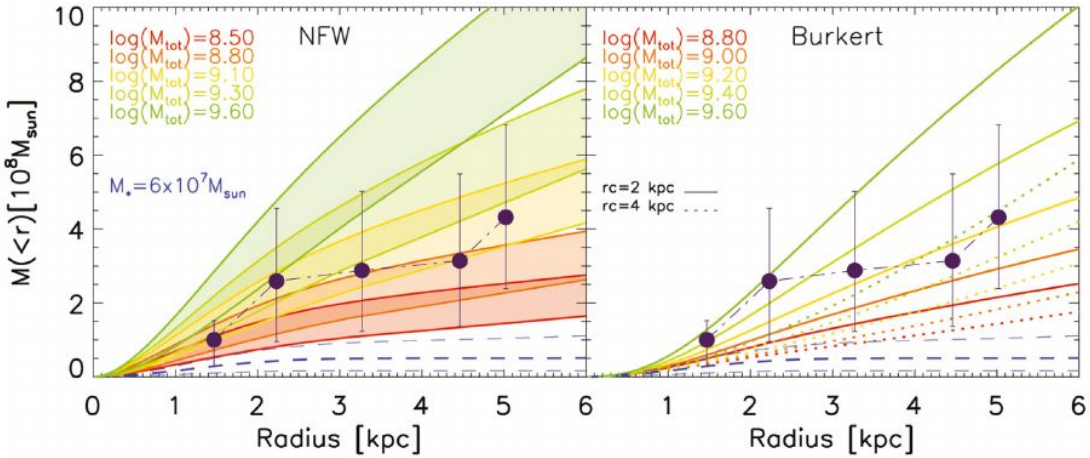


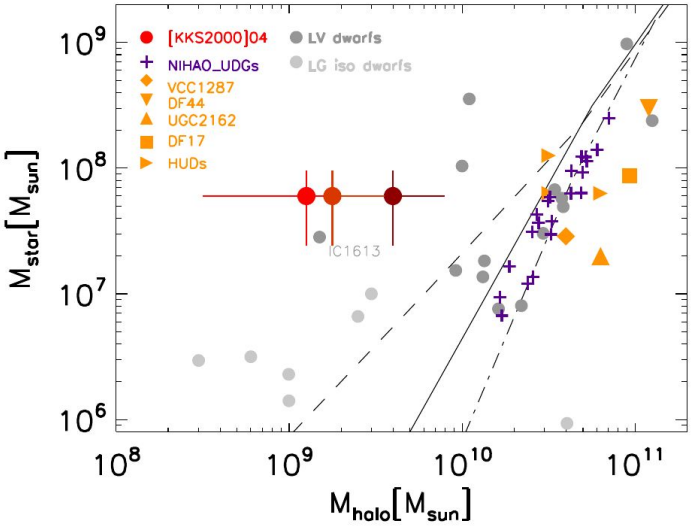


van Dokkum et al. (2018)

Maybe not too little dark matter

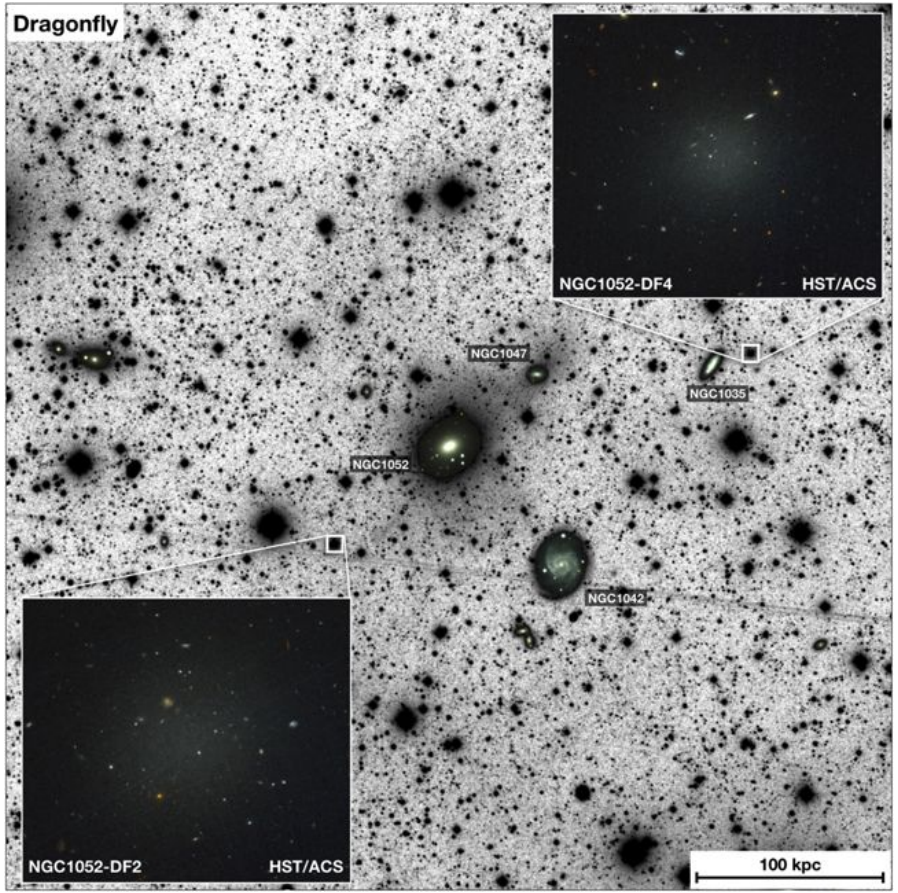
Revisiting the distance, there is plenty of room for dark matter





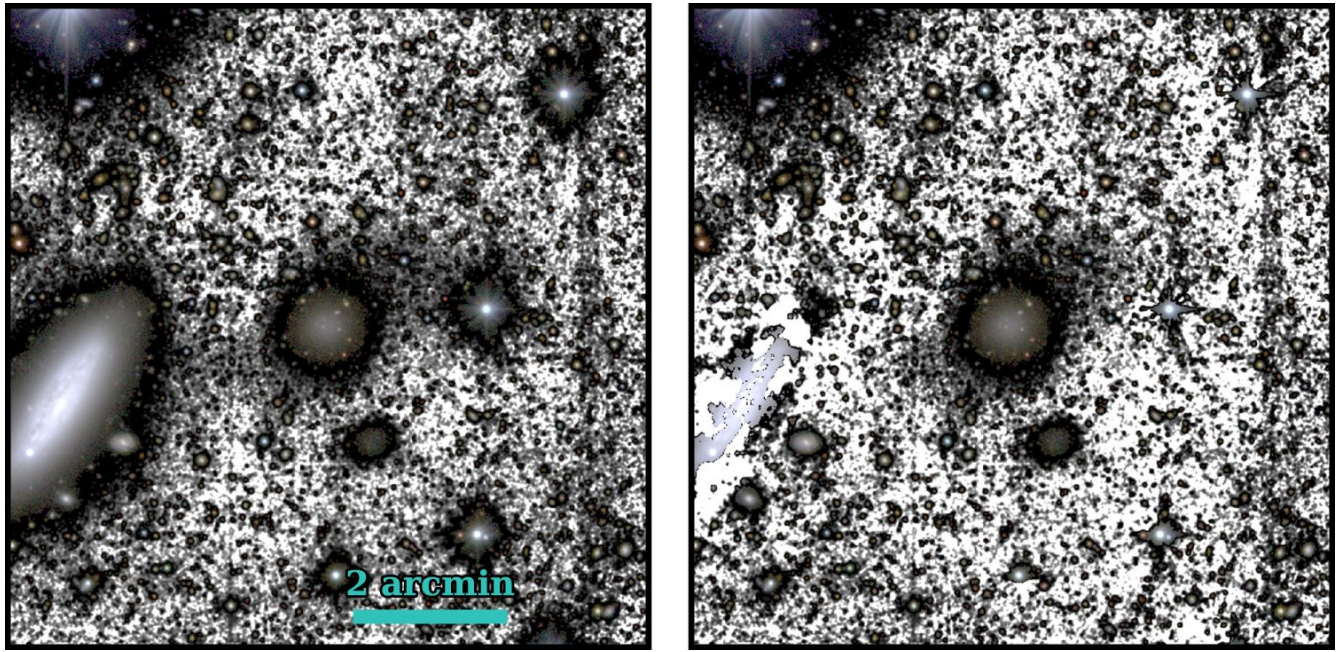
Trujillo et al. (2019)

NGC1052-DF4: a second galaxy missing dark matter



Credit: P. van Dokkum (Yale University)/STScI/ACS

NGC 1052-DF4 is undergoing tidal disruption



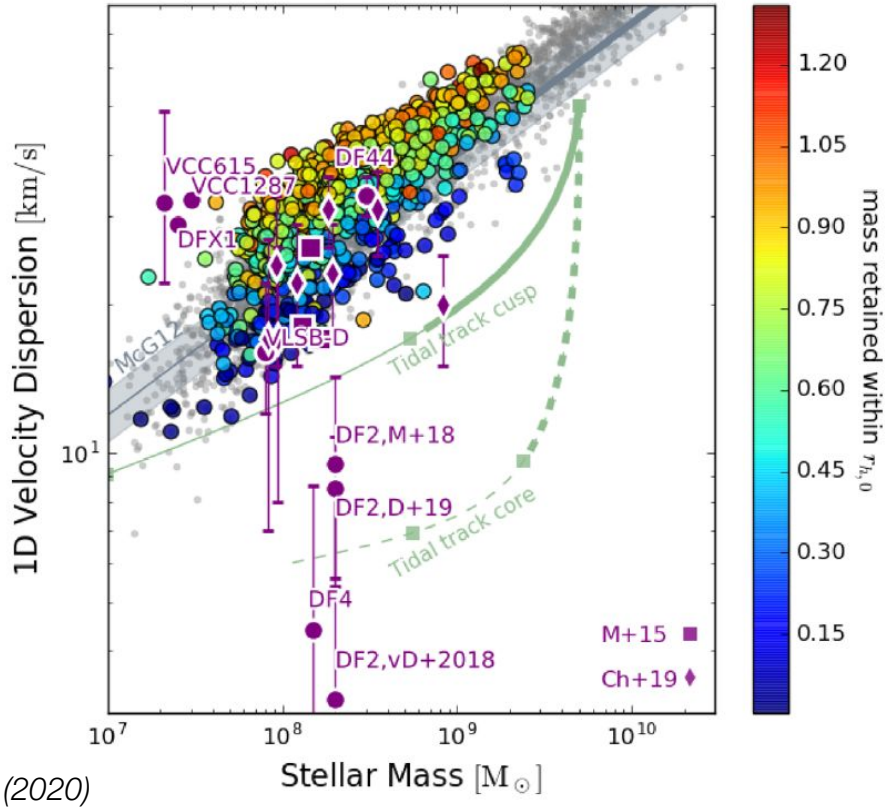
Montes et al. (2020)

How do they form?

- Are they failed L* galaxies?

- Do they live in dwarf halos?
  - High spin halos
  - Feedback-driven expansion
  - Tidal origin
    - *tidal interaction rarefy a satellite galaxy's structure (Carleton et al. 2019)*
    - *diffuse tidal dwarf galaxies in strong interaction event between two other larger galaxies (Bennet et al. 2018)*

Formation of UDGs in clusters in Illustris TNG

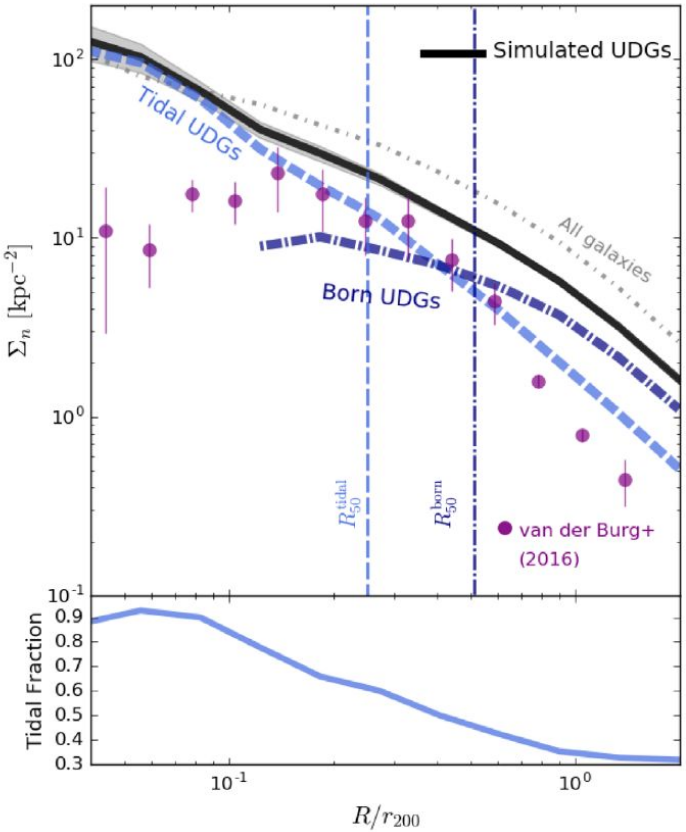


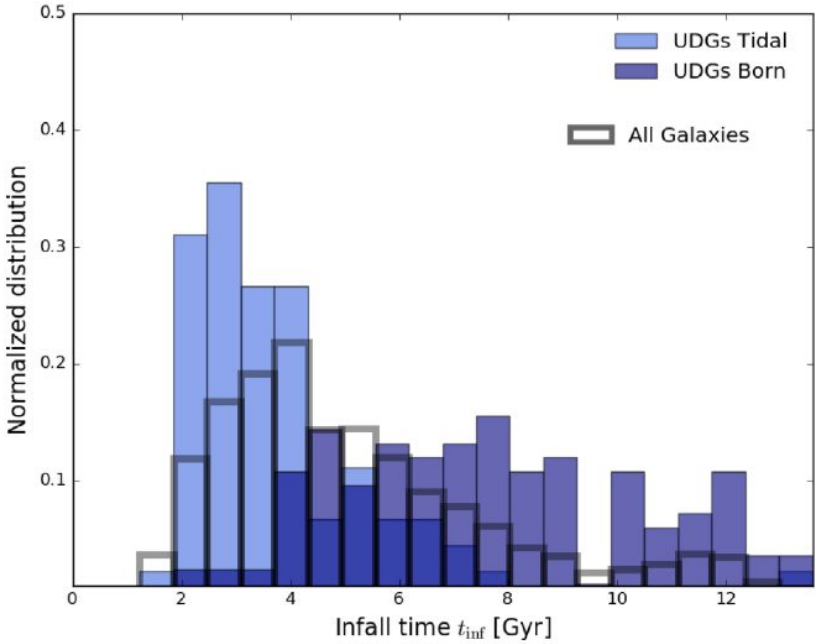
Sales et al. (2020)

Dual origin:

- Born UDG
- Tidal UDG

Formation of UDGs in clusters in Illustris TNG





Sales et al. (2020)

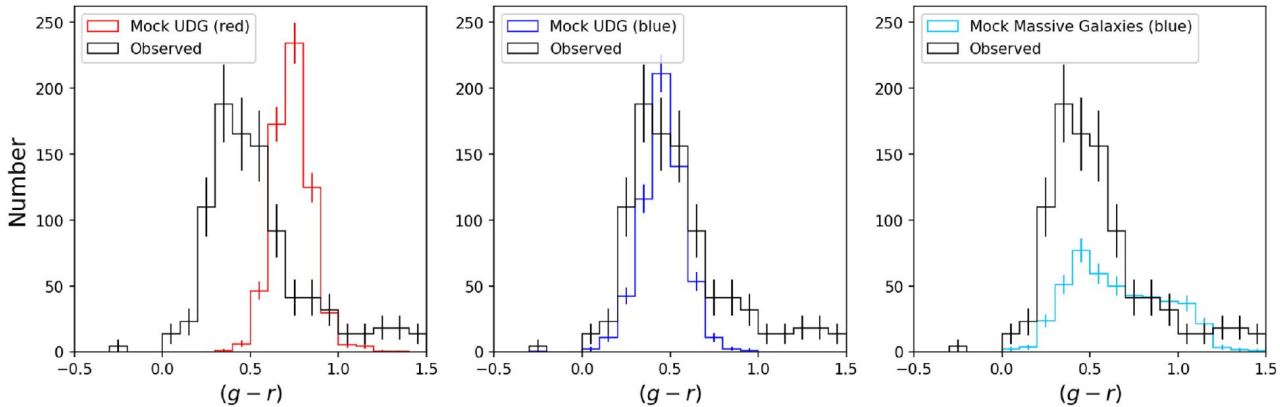
UDGs in the field

Most of observational studies are limited to UDGs in groups and clusters

The distance problem: it is harder to identify UDGs in the field

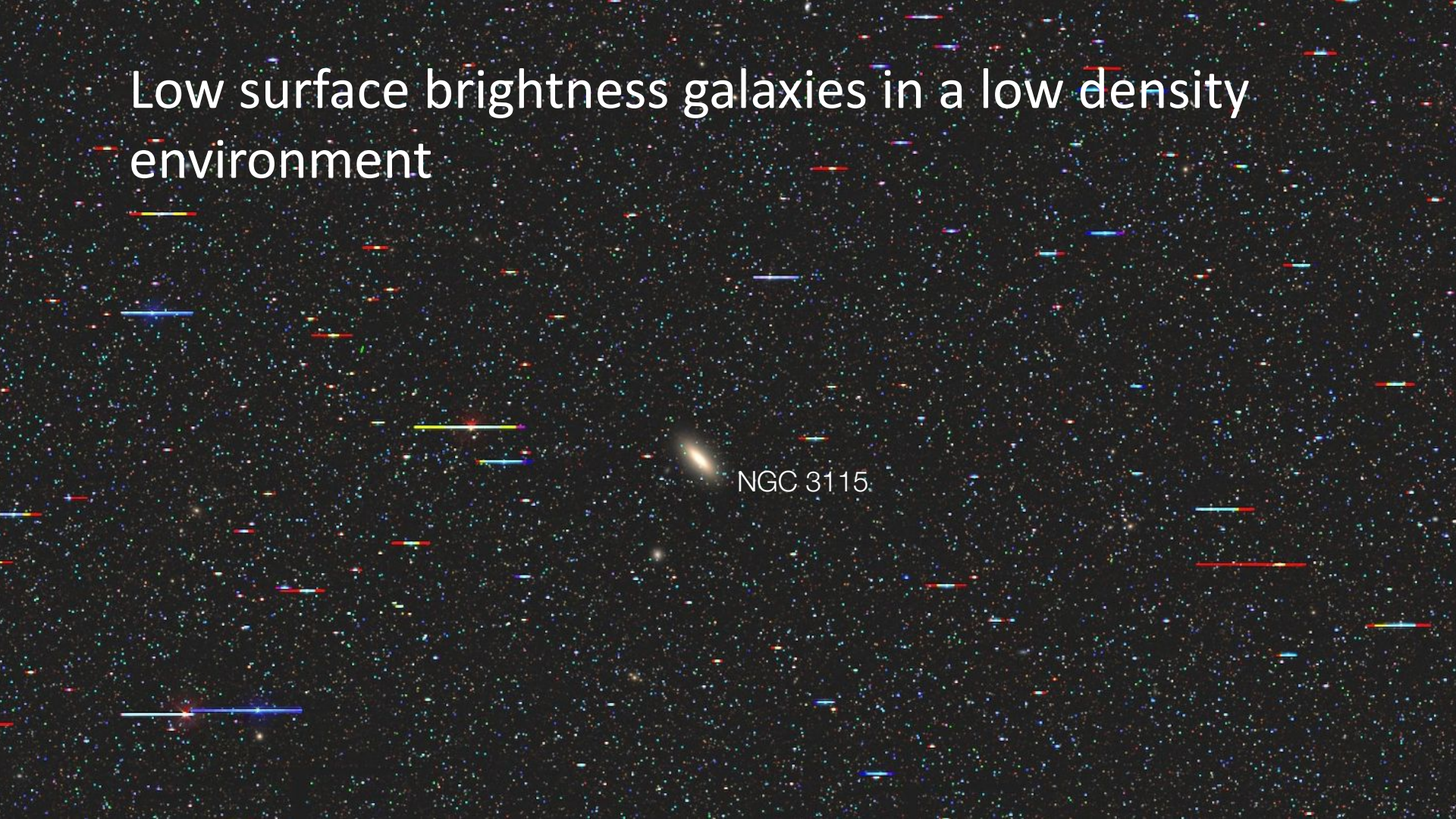
Statistical analysis of the UDG population in the field

UDGs in the field are predominantly blue and star-forming



Prole et al. (2019)

Low surface brightness galaxies in a low density environment



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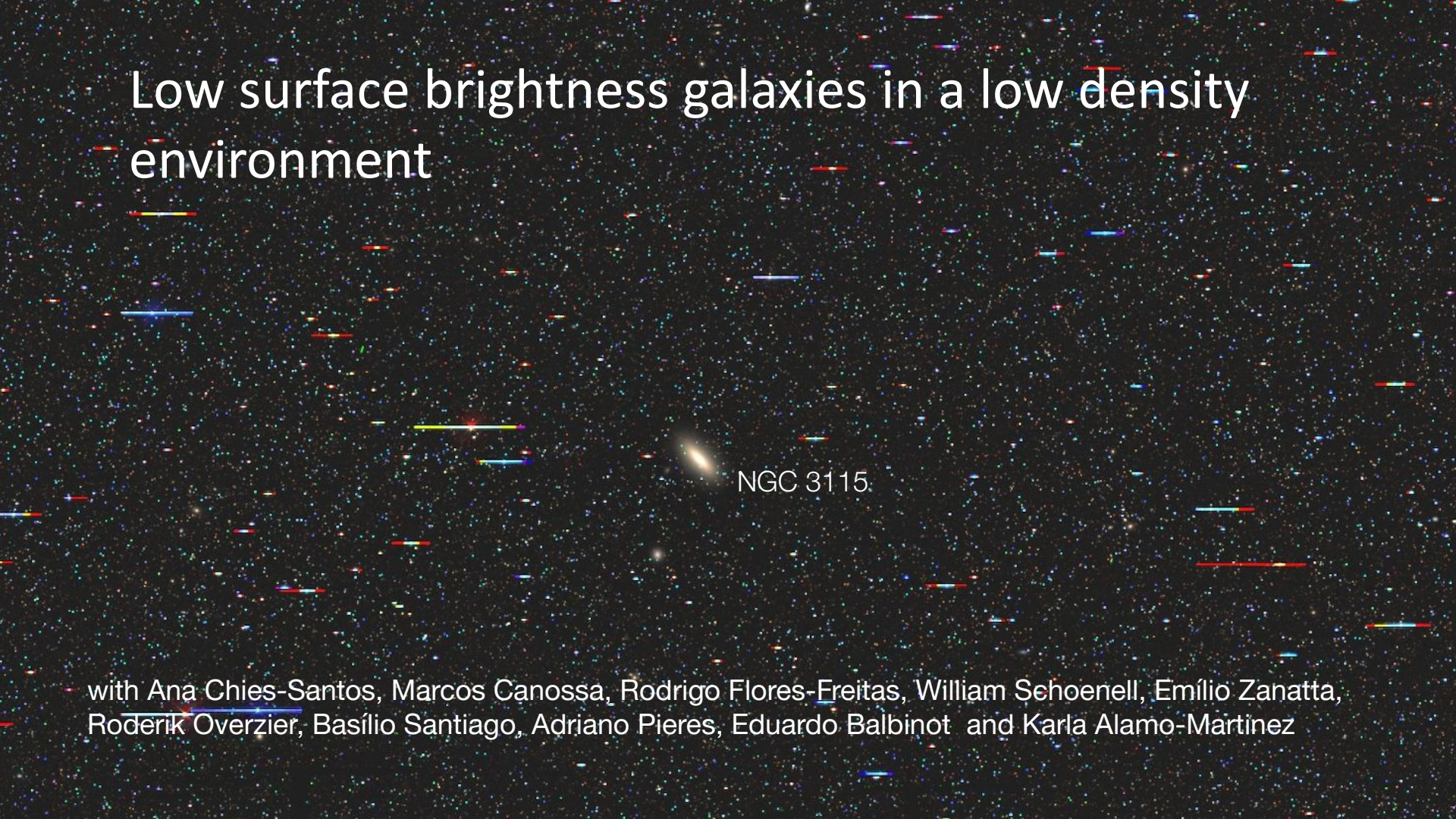


with Ana Chies-Santos, Marcos Canossa, Rodrigo Flores-Freitas, William Schoenell, Emílio Zanatta, Roderik Overzier, Basílio Santiago, Adriano Pieres, Eduardo Balbinot and Karla Alamo-Martinez

NGC 3115

Distance ~10 Mpc

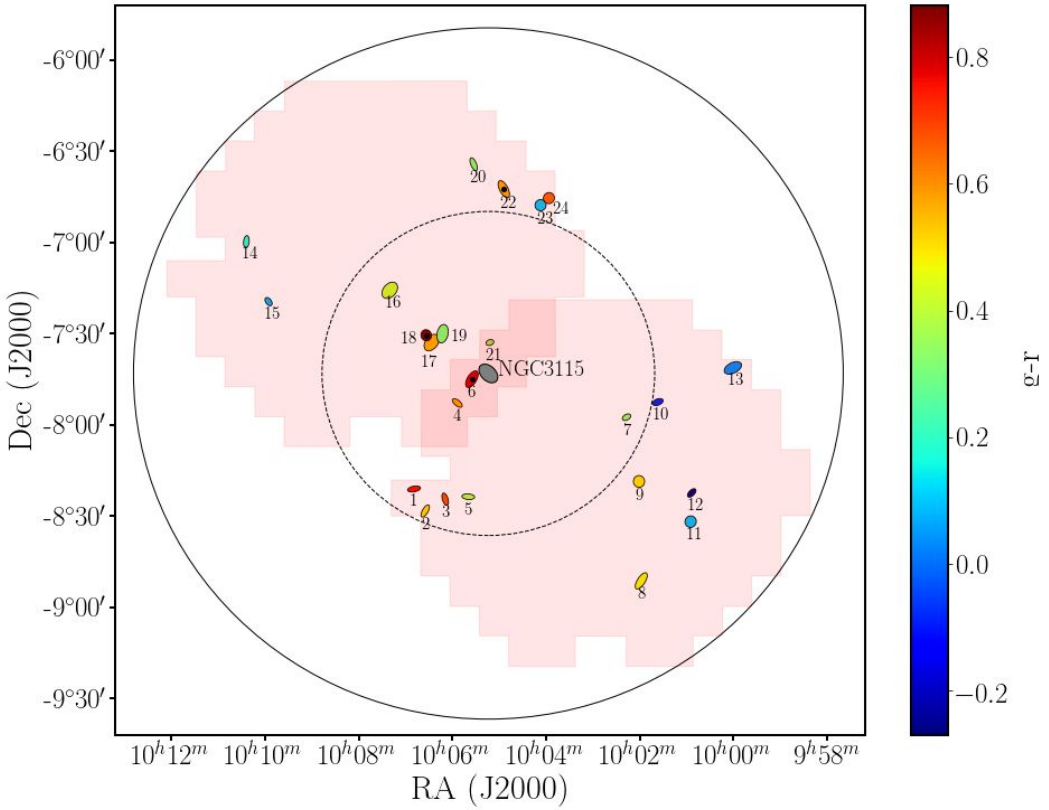
$M_{\star} \sim 10^{11} M_{\odot}$

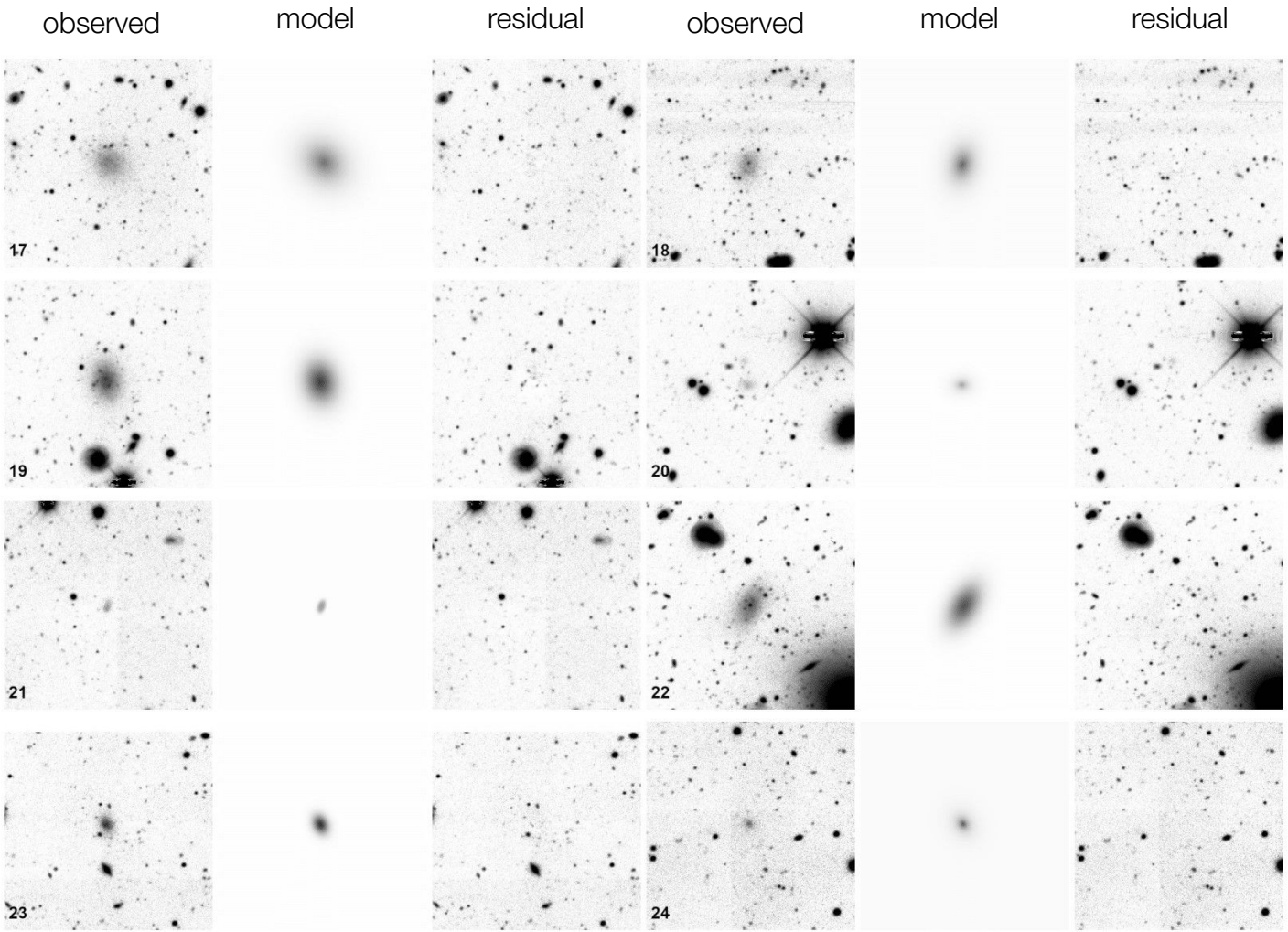
LSB galaxy candidates around NGC 3115

24 satellite candidates

18 reported for the first time

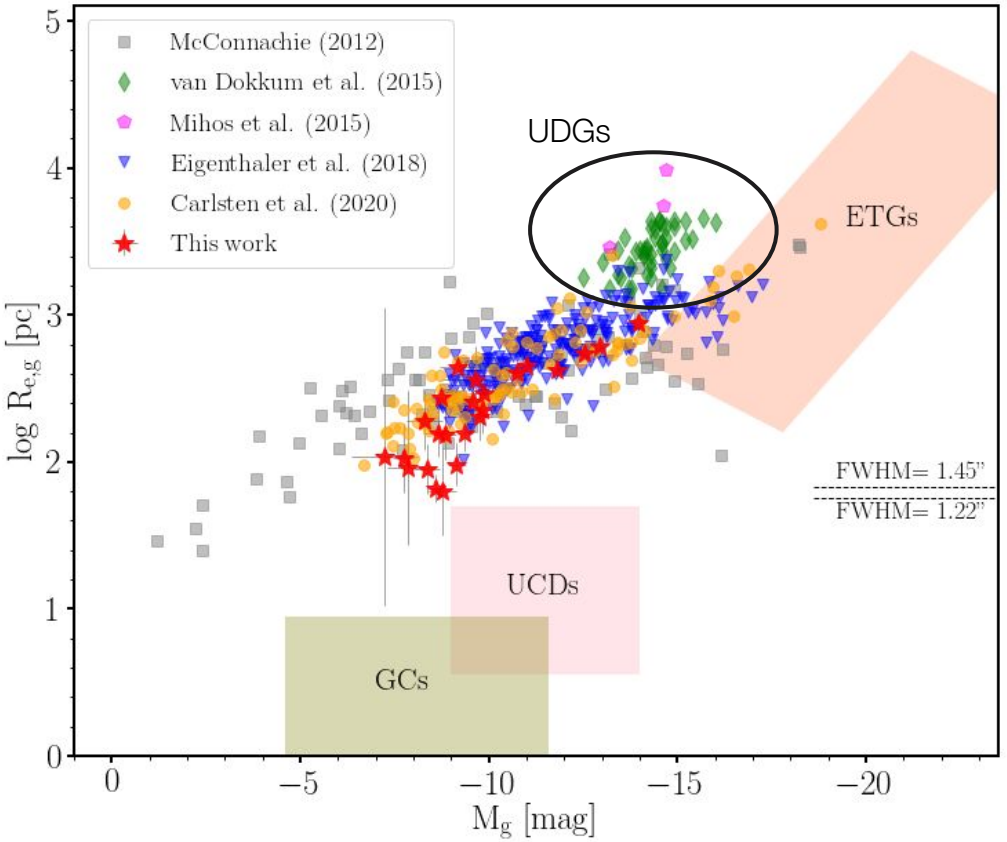
Trend: the larger the distance to NGC 3115, the bluer the satellite



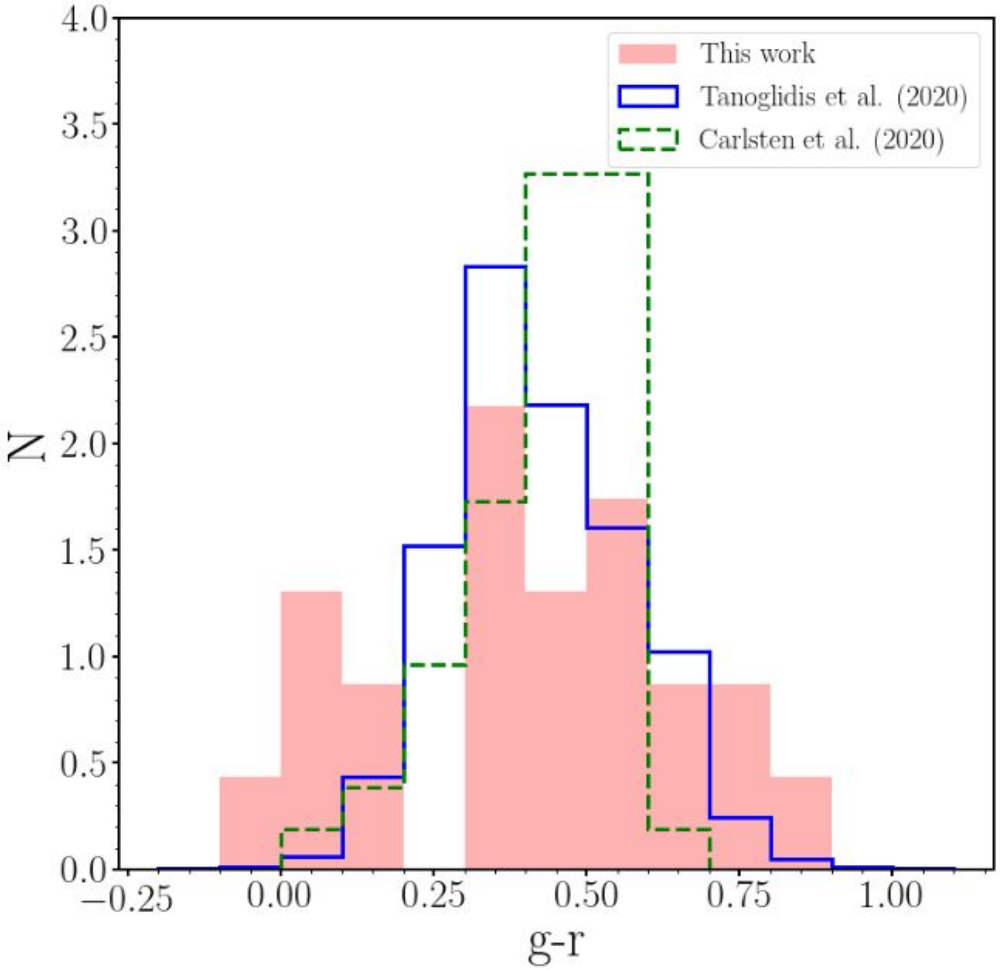

observed
model
residual
observed
model
residual
17
18
19
20
21
22
23
24

Our candidates are smaller and fainter than UDGs

LSB dwarfs

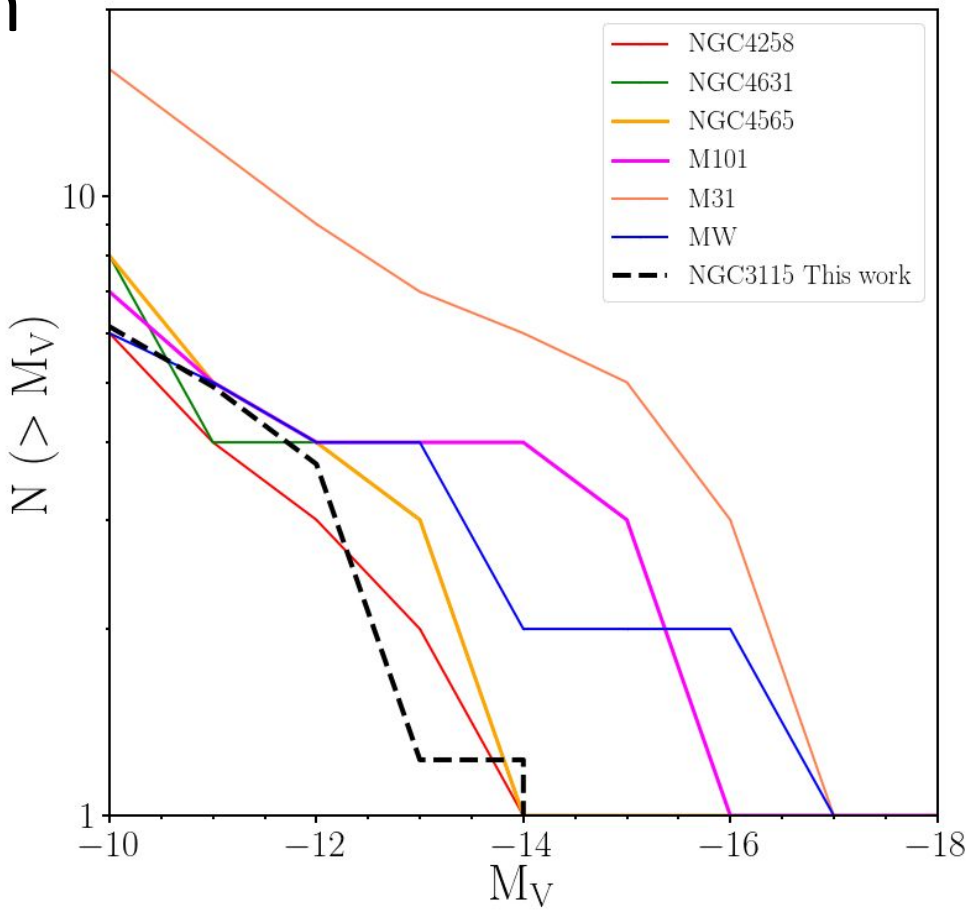


Colour distribution of our LSB dwarfs are similar to DES and Local Volume samples.



Luminosity function

Lack of bright satellites compared to other Local Universe galaxies of similar stellar mass



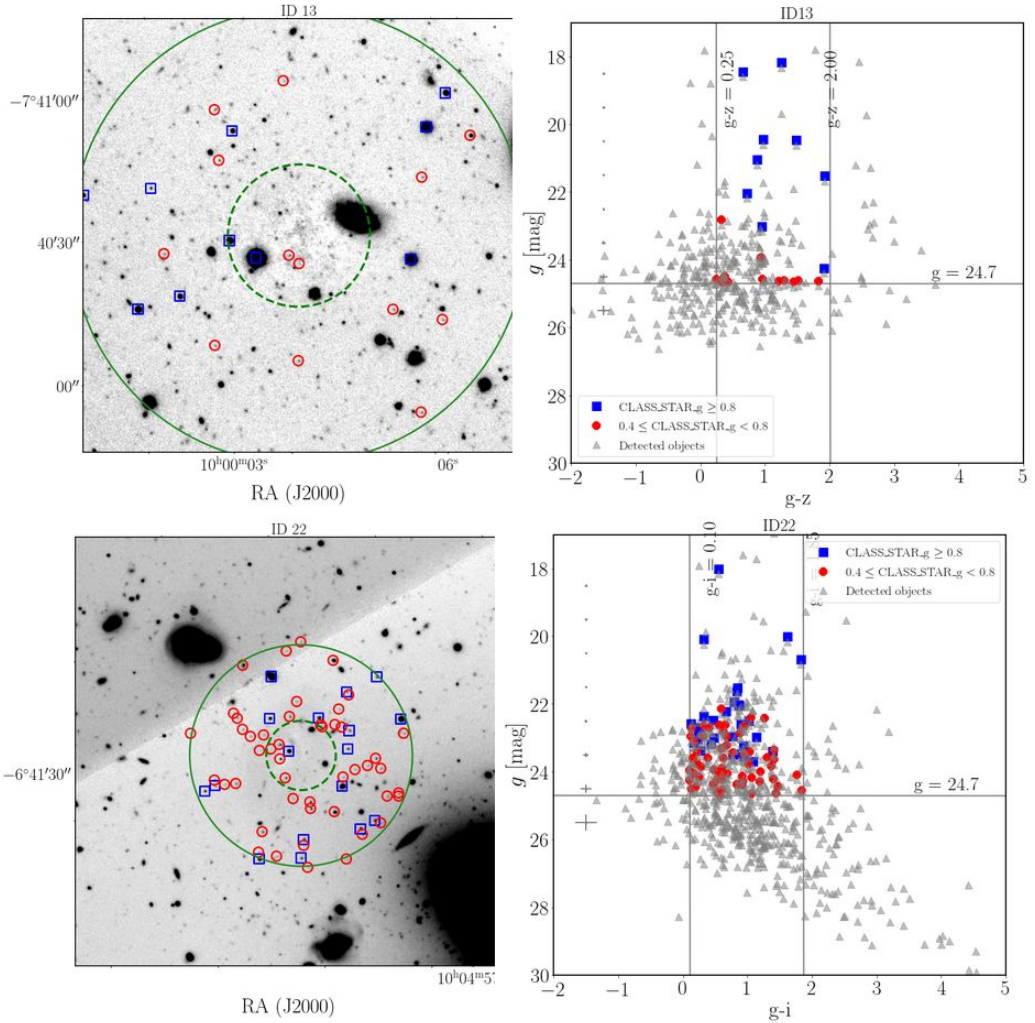
GC systems

Follow-up Gemini data

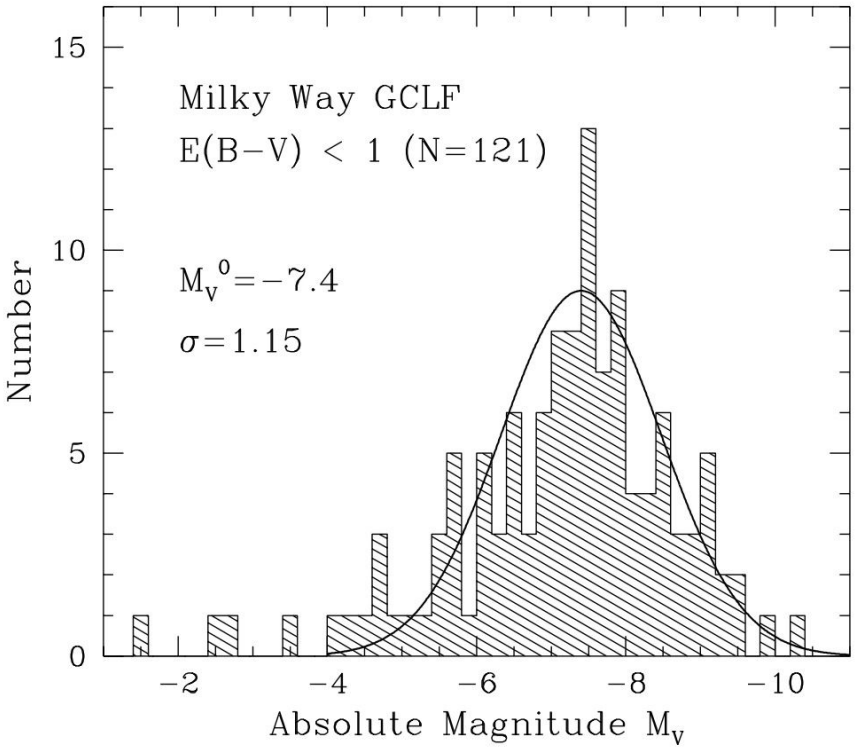
g, i and z imaging for 10 LSB dwarfs with higher concentration of point-like sources towards the centre

Selection of GC candidates based on typical colours

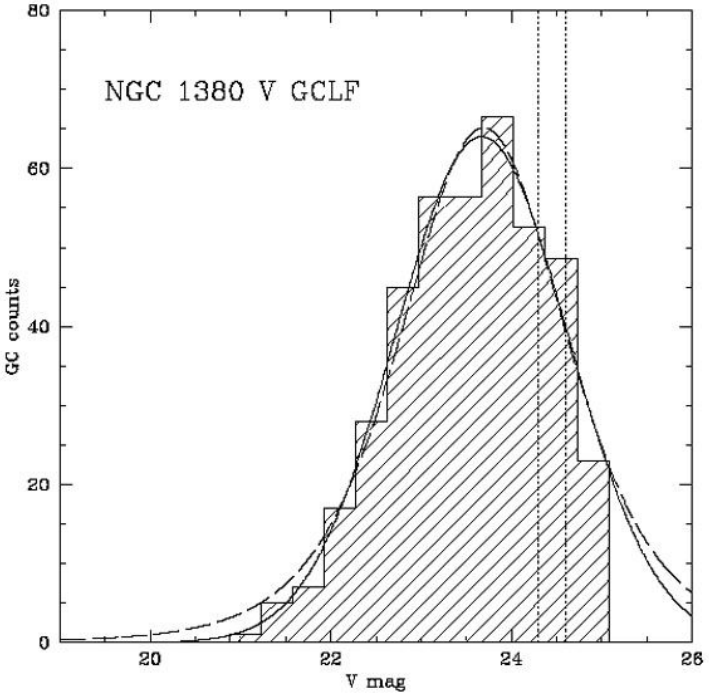
Marco Canossa (undergrad student)



GC Luminosity Function (GCLF)



Harris et al. (2000)

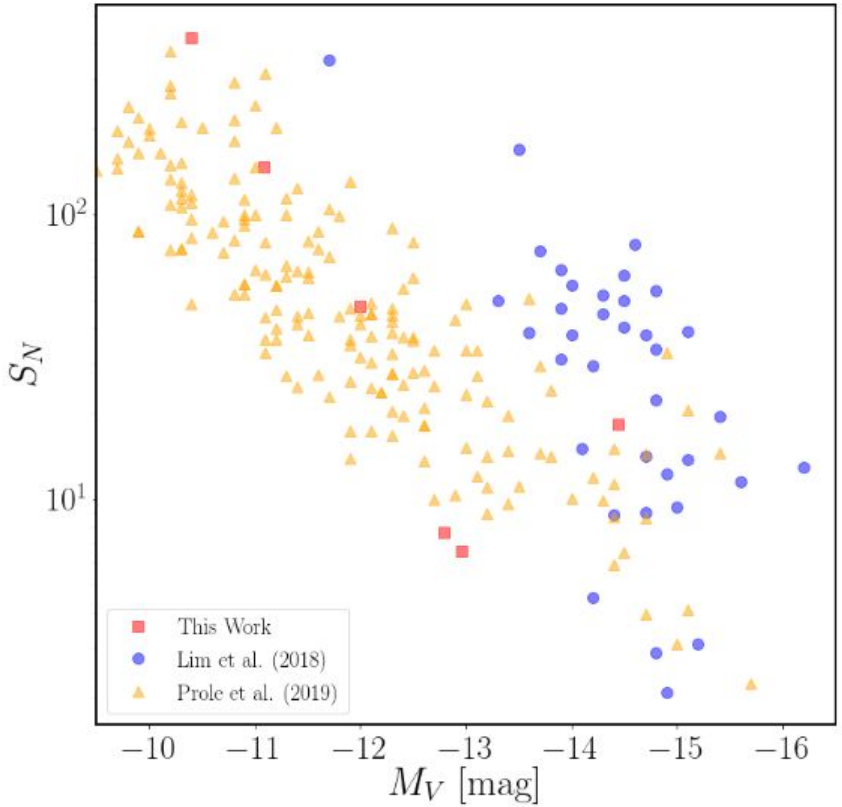


Della Valle et al. (1998)

Specific frequency

S_N = number of GCs per unit galaxy luminosity

Preliminary results indicate that S_N similar to values obtained for field UDGs



Use GCs as tracers for mass estimation

Under the hypothesis of spherical symmetry and dynamical equilibrium:

$$\mathrm{M}(< \mathrm{r}_{1/2}) \approx 3\mathrm{G}^{-1}\sigma^2_{\mathrm{los}}\mathrm{r}_{1/2}$$

Total mass within $r_{1/2}$

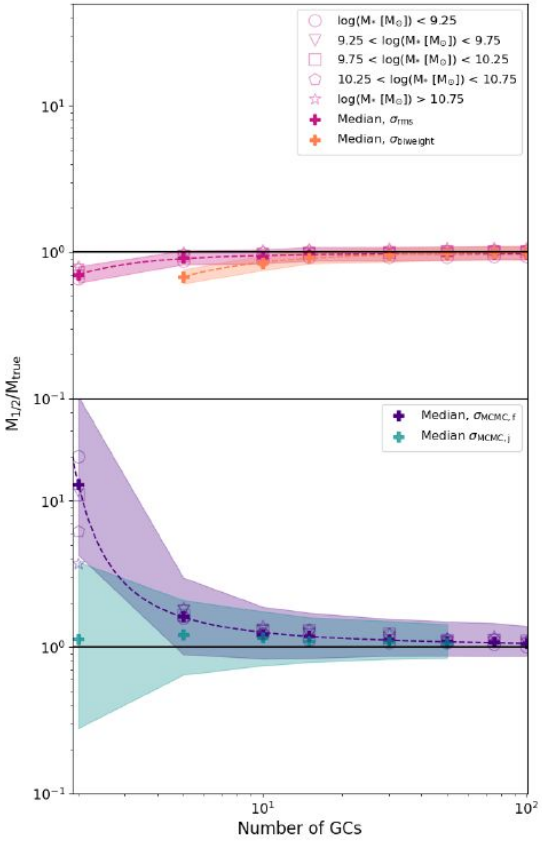
line-of-sight velocity dispersion

radius containing half of the tracer mass/light

In the case of our LSB dwarfs, what is the impact of a low number of GCs on mass estimation?

Use GCs as tracers for mass estimation

- GCs are reliable tracers of mass for galaxies with more than 10 GCs
- For galaxies with less than 10 tracers, the mass is underestimated
- Some calibrations can help alleviate these biases for some methods widely used in the literature



Doppel et al. (2020)

NGC 3115: the formation pathways of an isolated S0

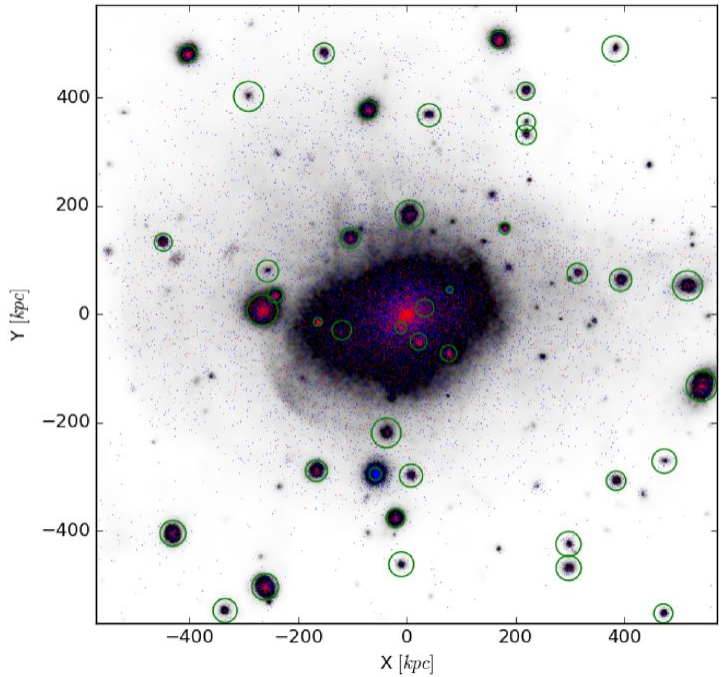
Credits: NASA, ESA, and J. Erwin (University of Alabama); Processing: Gladys Kober (NASA/Catholic University of America)

Identify analogs of NGC 3115 & get luminosity function and satellite properties in Illustris simulation

Morphological aspects of evolution and formation pathways of an isolated S0 galaxy type

Micheli Moura
(Phd student)

NGC 3115: the formation pathways of an isolated S0

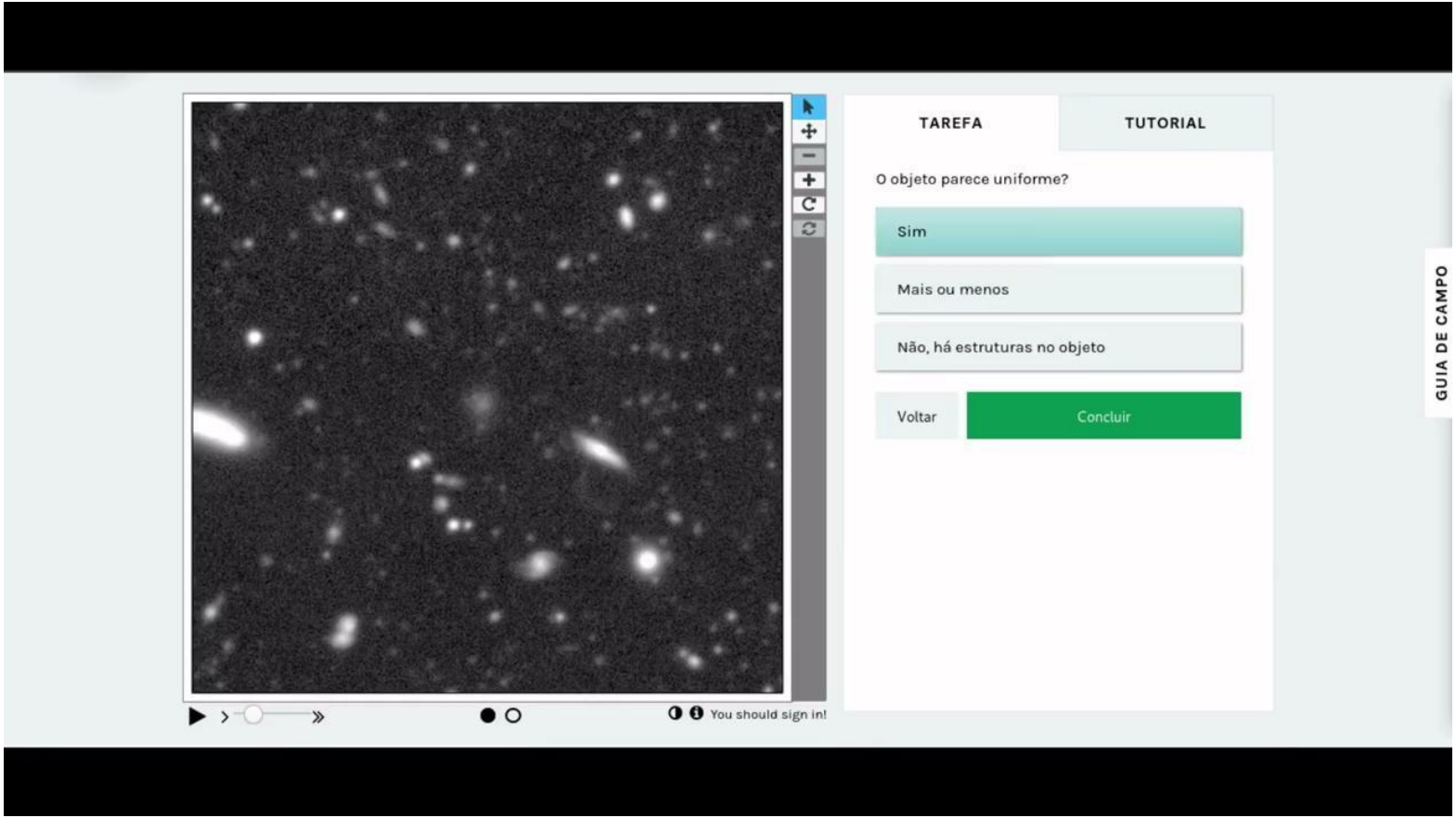


Ramos-Almendares et al. (2020)

Tagging technique: simulate the spatial distribution and kinematics of GCs within galaxies in Illustris

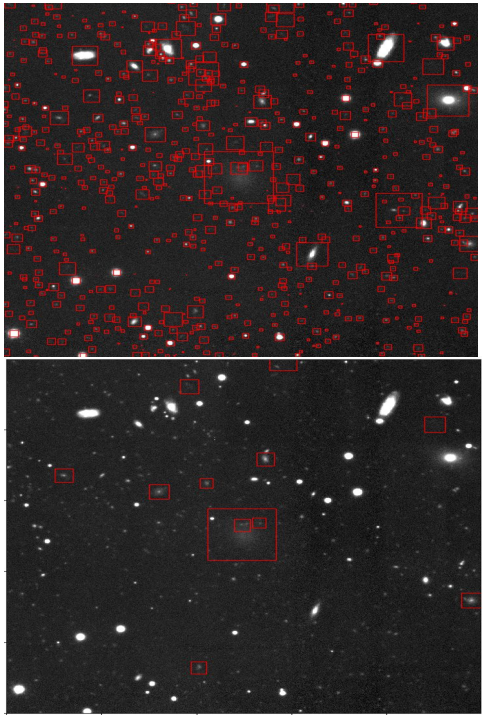
Micheli Moura
(Phd student)

Difuzoo

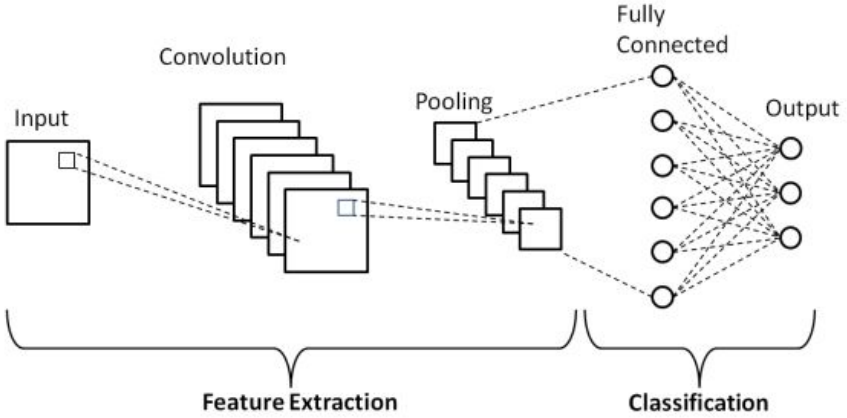

TAREFA
TUTORIAL
O objeto parece uniforme?
Sim
Mais ou menos
Não, há estruturas no objeto
Voltar
Concluir
GUIA DE CAMPO
You should sign in!

Deepfuse: using deep learning to find diffuse galaxies

automatic detection



classification by a convolutional neural network



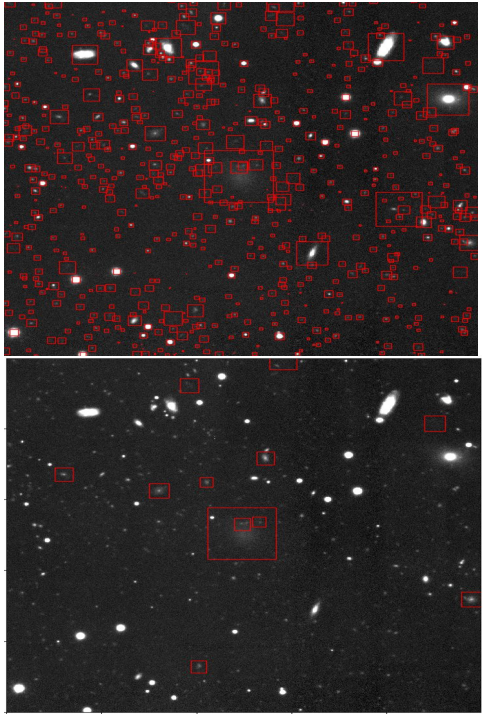
Test different CNN architectures and the usage of transfer learning

Training set of 40k images from Tanoglidis et al. (2020)

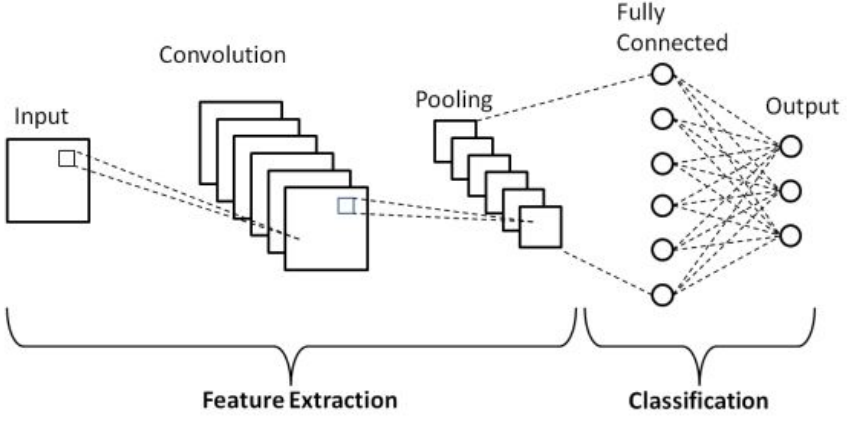
EfficientNet-B2 is able to classify LSBGs with an accuracy of ~92%

Deepfuse: using deep learning to find diffuse galaxies

automatic detection



classification by a convolutional neural network



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Thank you!