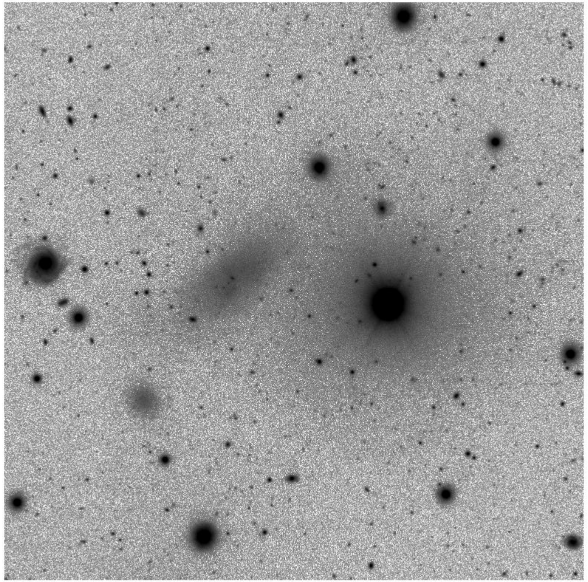
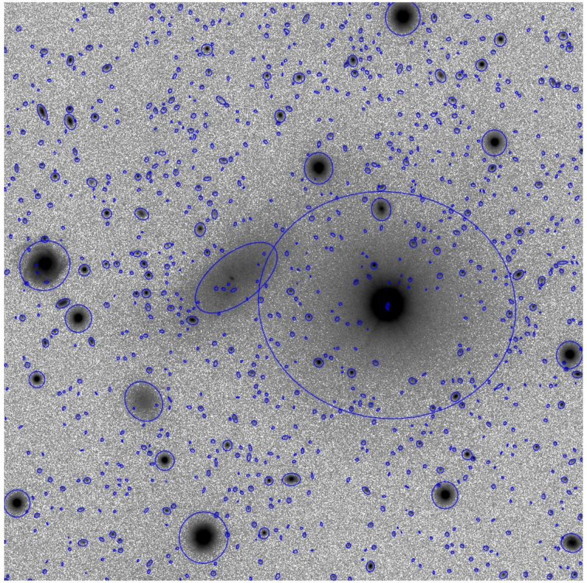
Automated searches for low surface brightness galaxies in wide area surveys





Daniel J. Prole

Supervisors: J. I. Davies (Cardiff), Michael Hilker & Remco van der Burg (ESO)

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Scientific Interest

The Ultra-diffuse galaxy (UDG):

Milky way sized (effective radii > 1.5 Kpc)

Stellar masses more like dwarfs (M_{*}~10^7 $M_{\odot}$)

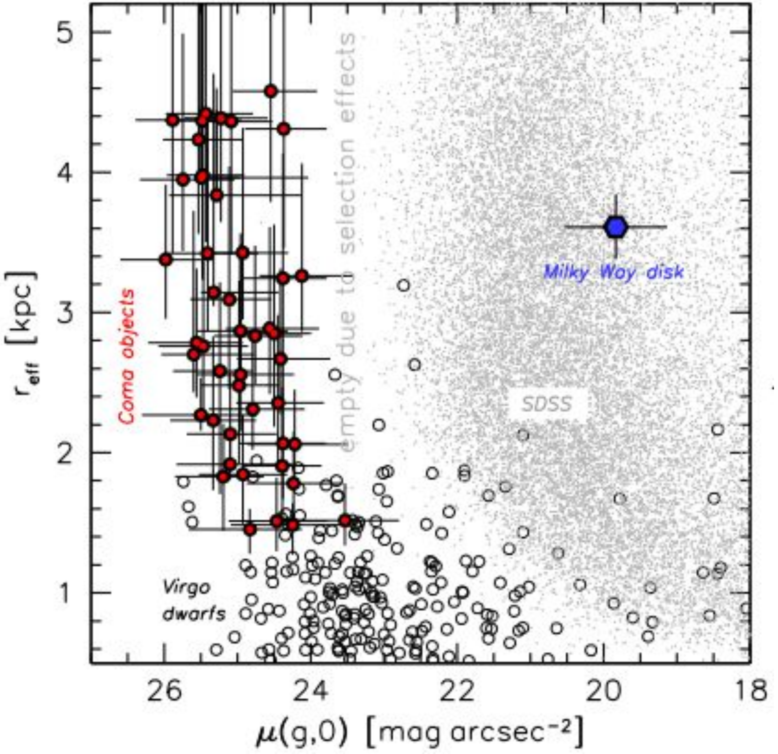
Abundant in high-density environments

UDG formation mechanisms:

“Failed L*” galaxies (van Dokkum et al. +15)

High-spin dwarfs (Amorisco & Loeb +16)

Tidal formation (Carleton et al. +18)



Van Dokkum et al. (2015)

Scientific Interest: UDG formation

Open questions:

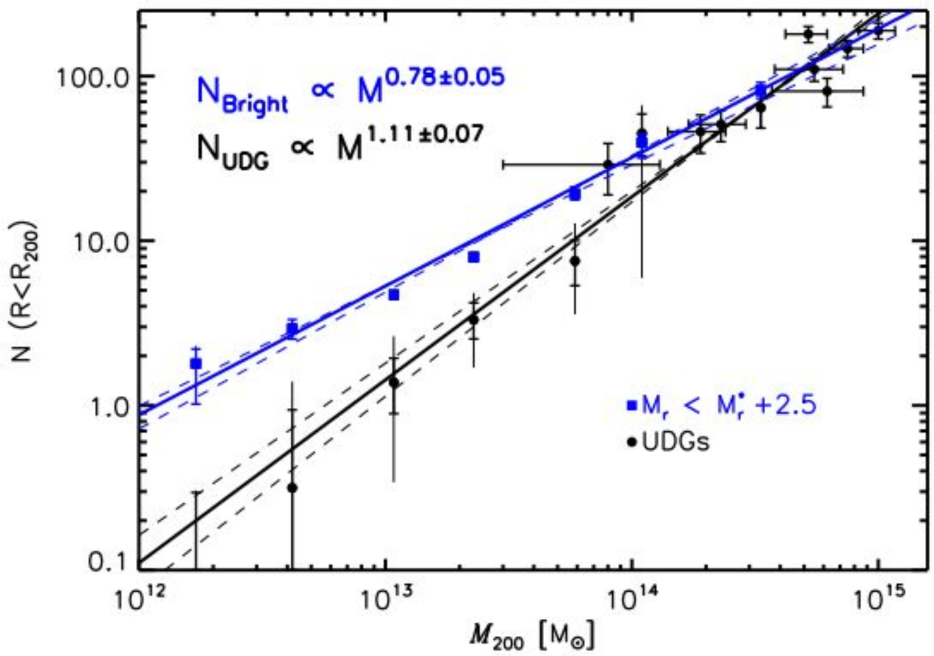
Why are UDGs relatively more abundant in high mass environments?

What are their formation mechanisms?

Key measurements:

Abundance as a function of environment

Halo mass



Van der Burg et al. (2017)

Scientific Interest: UDG halo mass

Kinematic observations:

e.g. 30+ hours on Keck II (van Dokkum et. al +16)

Weak lensing:

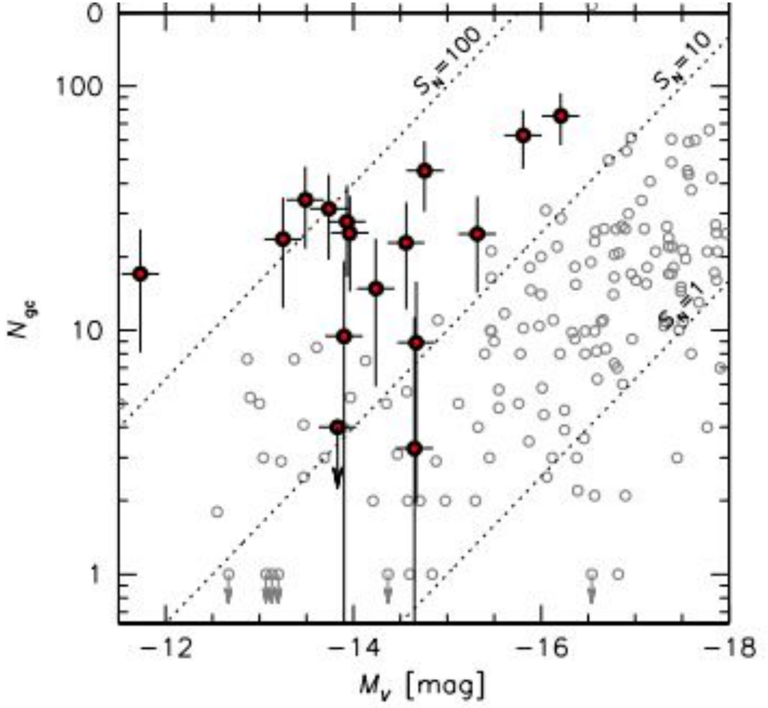
Constraints on *average* mass (Sifon et al. +17)

Tidal features (e.g. Mowla et al. +17):

Absence in Coma UDGs implies high ML ratios

Globular cluster systems (e.g. Beasley et al. +16):

Correlation between Ngc and halo mass



van Dokkum et al. 2017

Science goals & data

LSB galaxies in clusters	Fornax (FDS; Iodice et al. 2016) Hydra (VEGAS; Capaccioli et al. 2015) Virgo (NGVS; Ferrarese et al. 2012)	Size / mass distributions Nucleation fractions Globular cluster populations
UDGs in the field	KiDS (Kuijken et al. 2015) + GAMA (Driver et al. 2011)	Abundance & formation efficiency

ESO Studentship until February 2019

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Detection methods

Source Extractor (Bertin & Arnouts 1996)
-Nested sources with multi-threshold deblend

DeepScan (Prole et al. 2018)
-Density-based detection of extended LSB structure

MTObjects (Teeninga et al. 2016)
-Max-tree structure with continuous threshold deblend

ProFound (Robotham et al. 2018)
-Watershed deblend + iterative segment dilation

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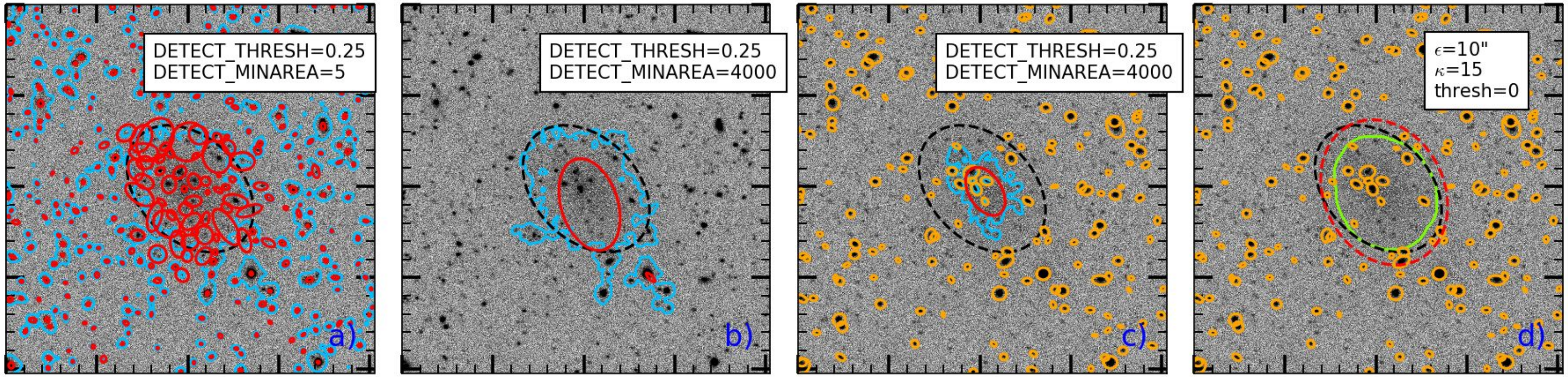
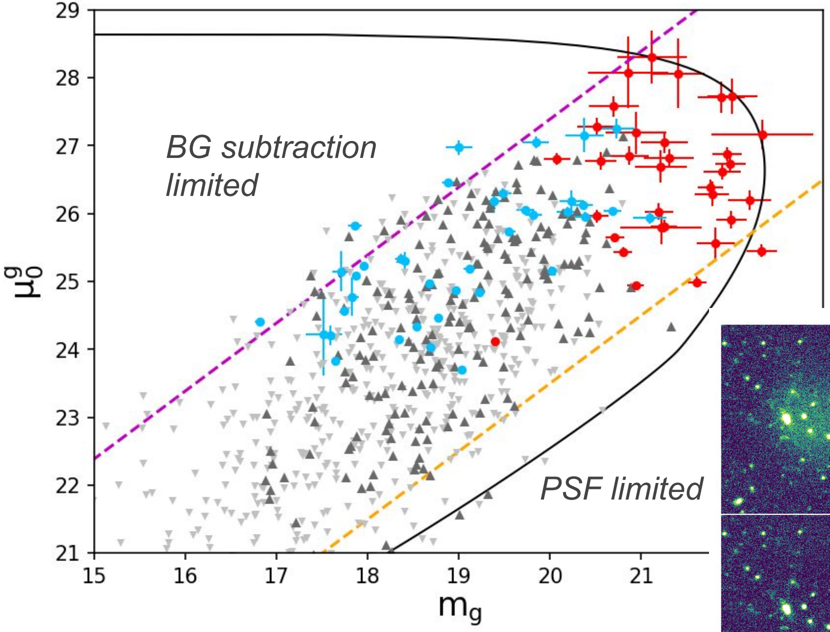
Detection methods: SExtractor



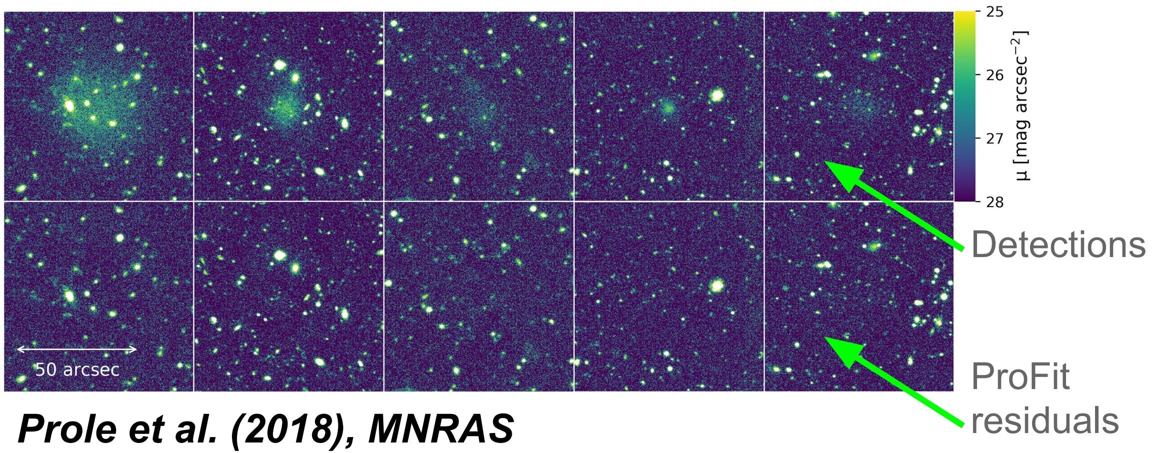
Fragmentation ("shredding") | Confusion | Parameter Underestimation | DeepScan

Blue: SExtractor segmentation map
Unbroken red: SExtractor FLUX_RADIUS
Orange: Masked

Detection methods: DeepScan



- 30 new detections over 5 degrees^2 in public NGVS data (red points)
- Stellar masses in range 10^6-10^7 $M_\odot$
- Problem of miss-detections



Prole et al. (2018), MNRAS

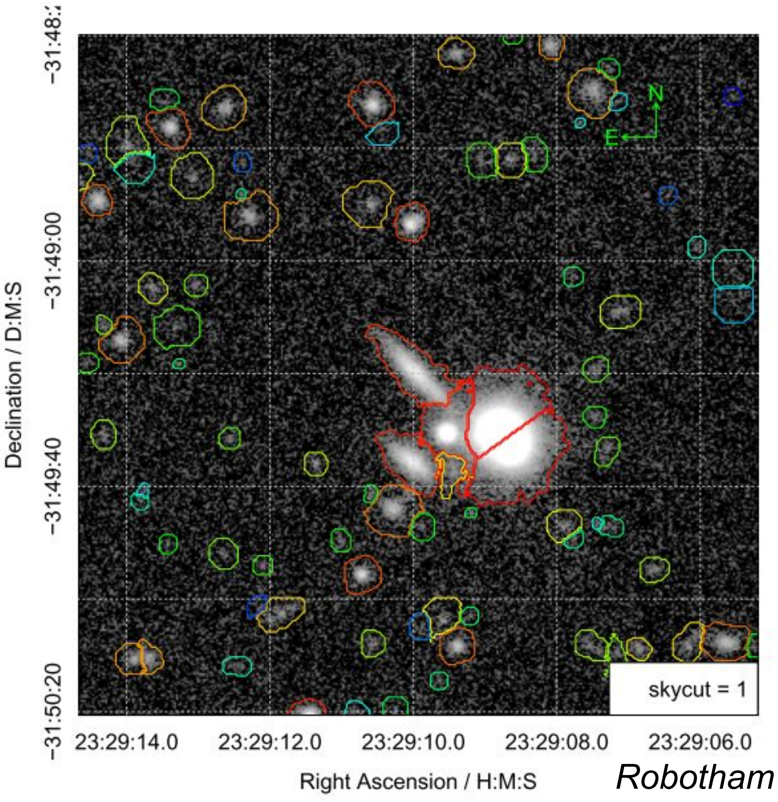
https://github.com/danjampro/DeepScan

Detection methods: ProFound

- Sky estimate (mesh)
- Single detection threshold
- **Watershed deblend**
- Sky estimate (mesh)
- Measure segment stats
- **Segment dilation**

Iterative (Sky estimate (mesh), Measure segment stats, Segment dilation)

https://github.com/asgr/ProFound

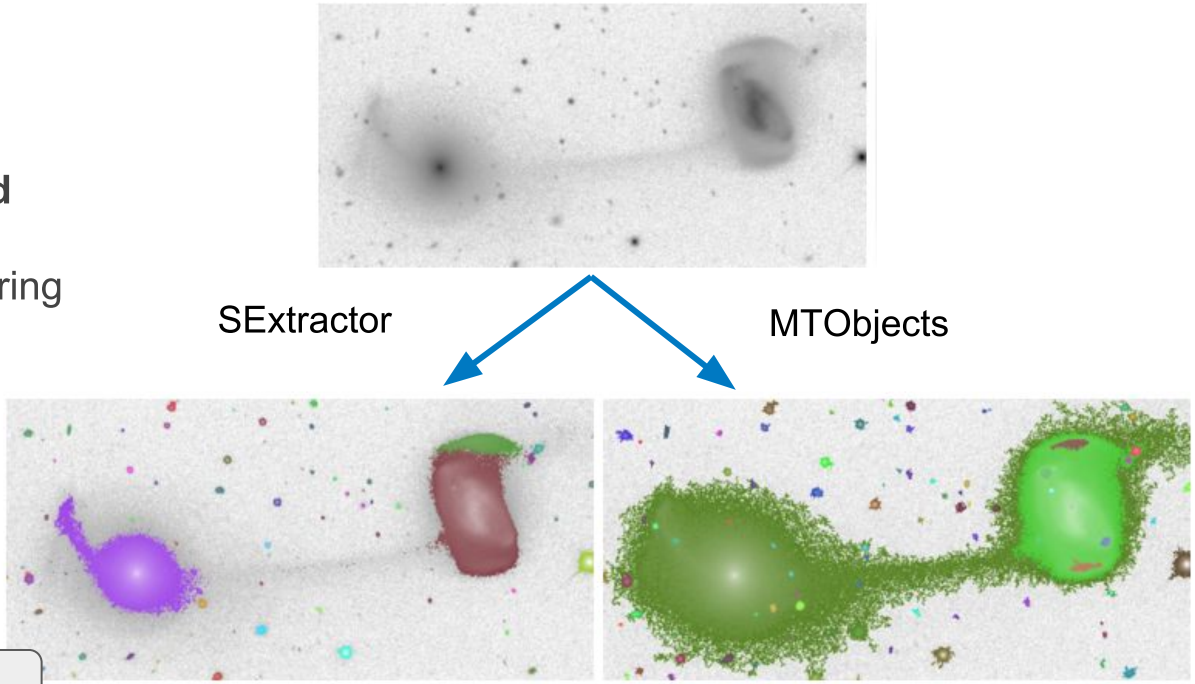


Robotham et al. (2018)

Detection methods: MTObjects

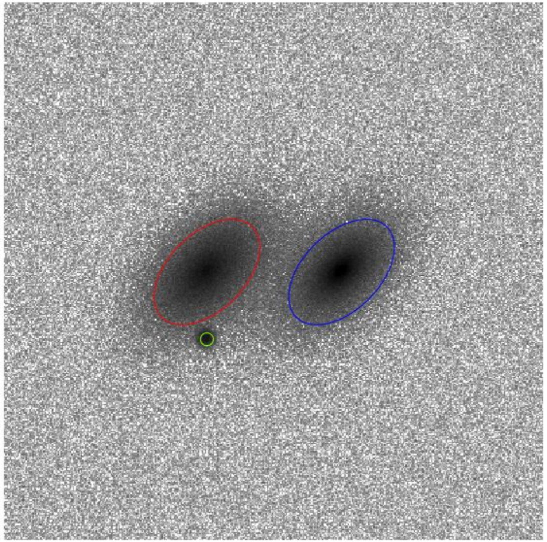
- Global sky estimate
- **Continuous threshold**
- Statistical attribute filtering
- Max-tree structure **(nested sources)**
- Source measurement

Under development

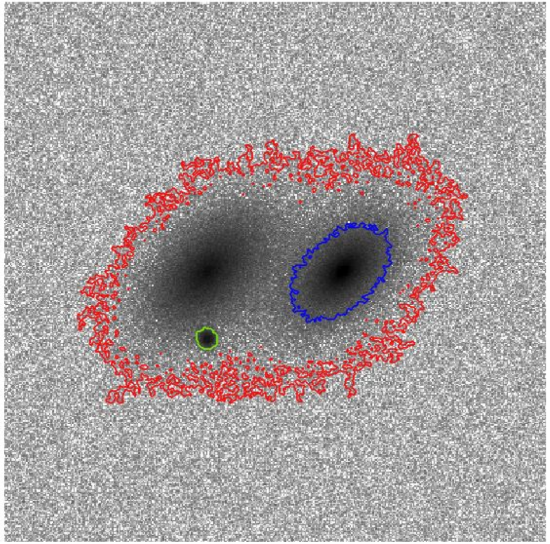


Teeninga et al. (2016)

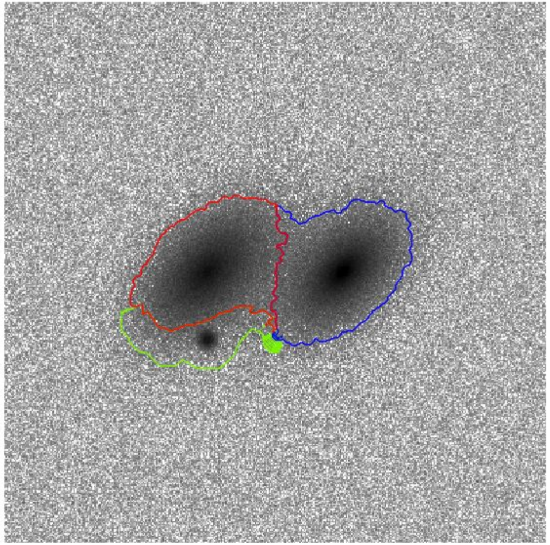
Detection methods: Comparison



Original



MTObjects



ProFound

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Which is the best?

… depends on the environment!

	The Good	The Bad
DeepScan	No fragmentation Detection of v. diffuse sources	No nested sources Source confusion
ProFound	Well developed / documented Useful output catalogue	No source nesting Halo fragmentation
MTObjects	Nested sources Extended structure not fragmented	LSB halo confusion Parameter uncertainty for nested sources

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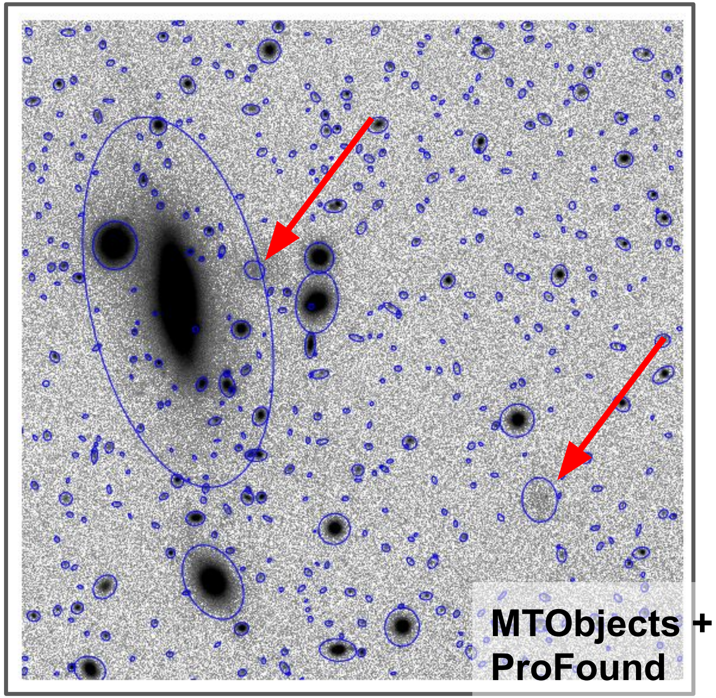
SG1: Fornax LSB inventory with FDS

Aim to build on by-eye classification of **Venhola et al. (2017)**

Problem of extended LSB halos from bright sources…

- Traditional BG subtraction not optimal
- Need to develop pre-selection and measurement strategies
- Also to define "**metric of success**"



MTObjects + ProFound measurement

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SG2: UDG field abundance with KiDS

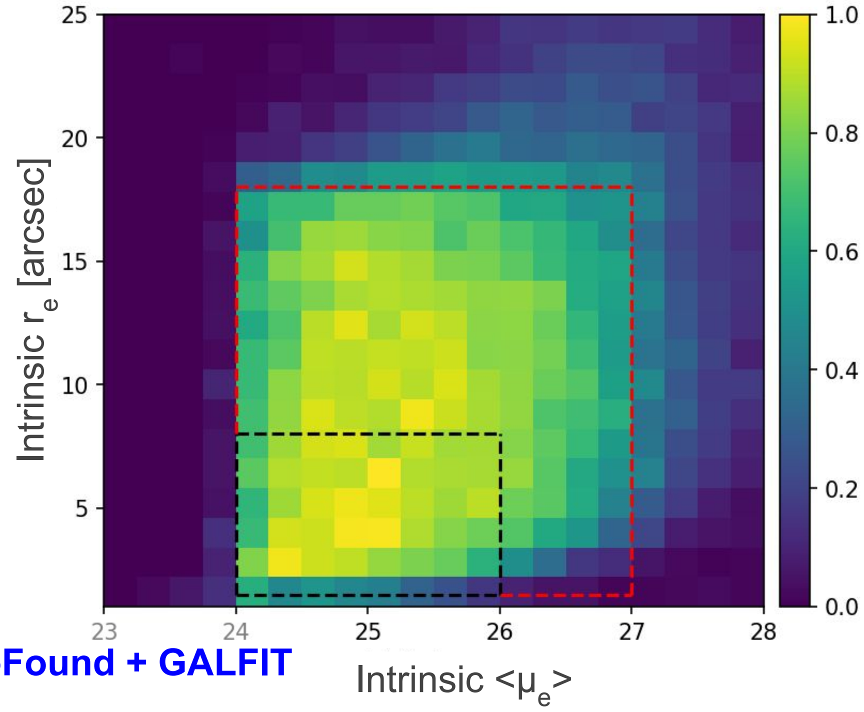
Want to constrain UDG abundance in low-density environments...

→ Need an observational sample of isolated sources

Why KiDS?

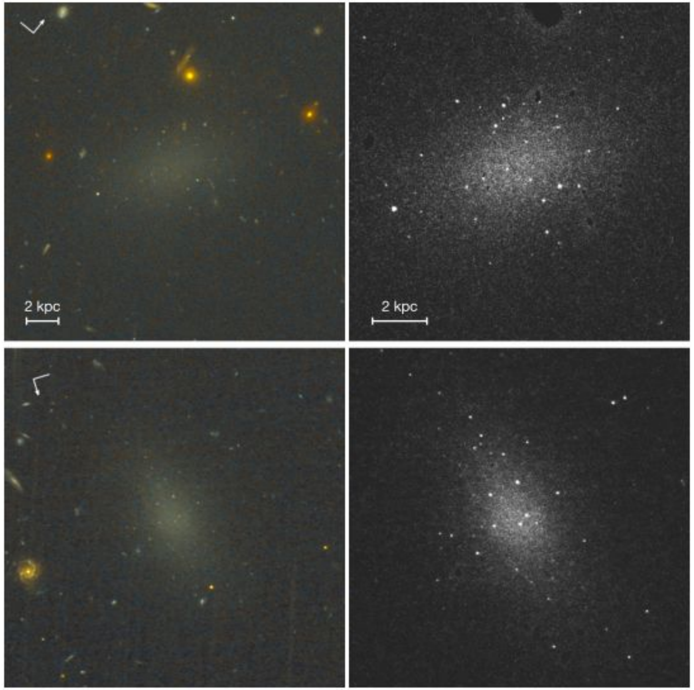
- Wide area, GAMA overlap
- Background subtracted, masks and weight maps

Detection efficiency from synthetic sources

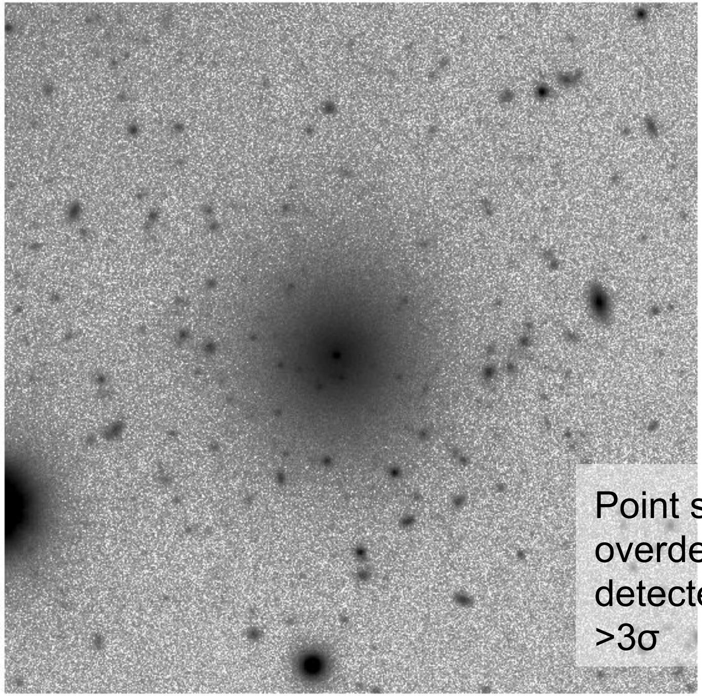


ProFound + GALFIT

SG3: Fornax UDG globular clusters



Coma UDGs with HST (van Dokkum et al. 2017)



Point source overdensity detected at >3σ

A Fornax UDG in FDS (r)

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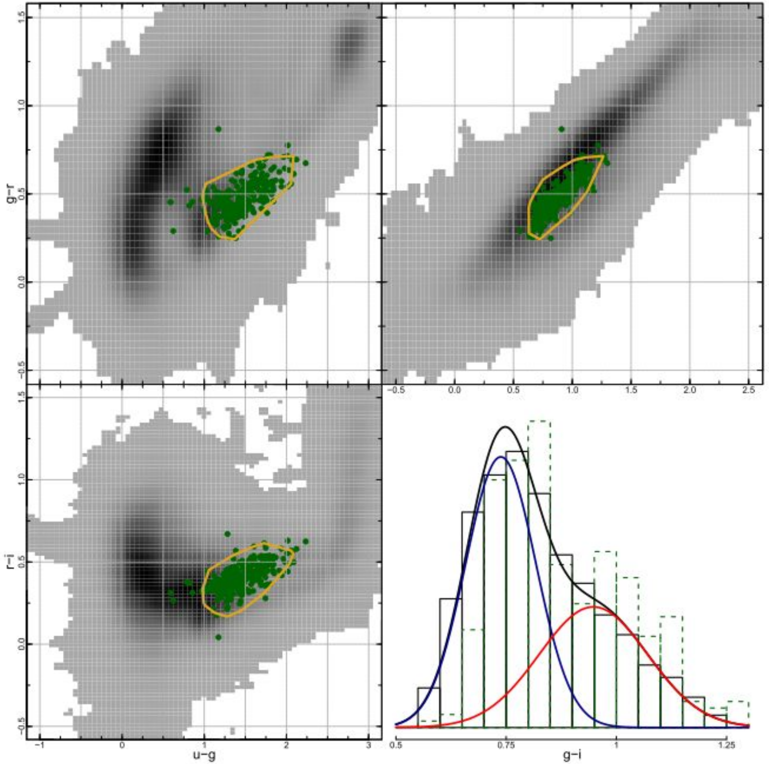
SG3: Fornax UDG globular clusters



+PCA Colour selection based on FDS training set (D'Abrusco et al. 2016)

Summary

	Science	Data	Tool
Field UDG abundance	Formation efficiency	KiDS + GAMA	ProFound
LSBGs/UDGs in Clusters	Spatial distributions	FDS + NGVS	MTObjects
GC systems of UDGs	Halo masses	FDS	ProFound

To do:

Refine detection + **measurement** algorithms

Define “**metric of success**” for meaningful algorithm comparisons

Quality control

Completeness / detection efficiency:

Fraction of sources with <μe>, re that are detected **AND** recovered in final sample

Can be measured with synthetic source injections

Purity:

Fraction of sources in sample that have intrinsic <μe>, re meeting selection criteria

Non-trivial to estimate automatically; in clusters can use statistical correction

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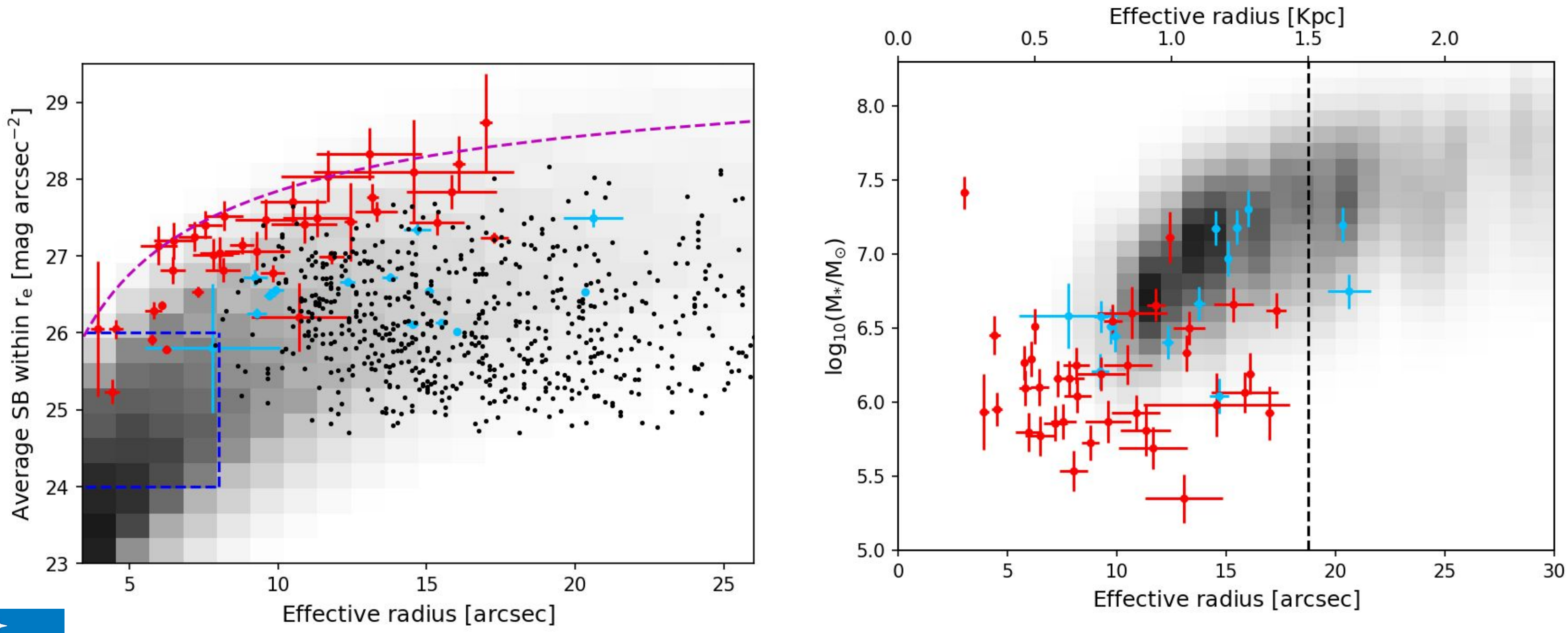

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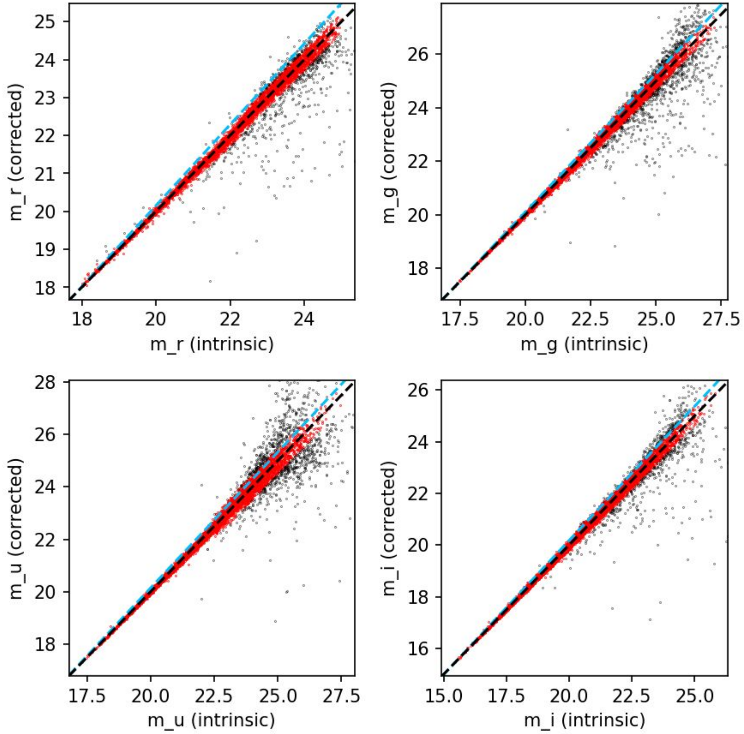
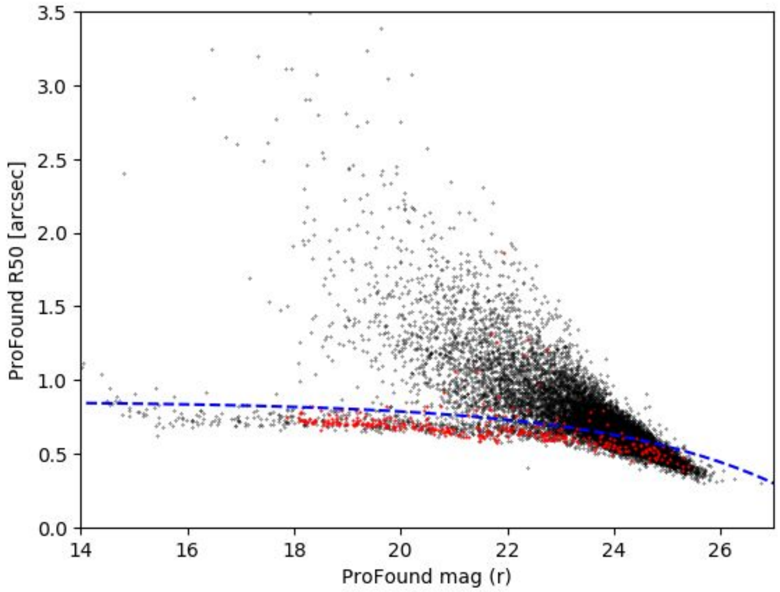
SG3: Fornax UDG globular clusters

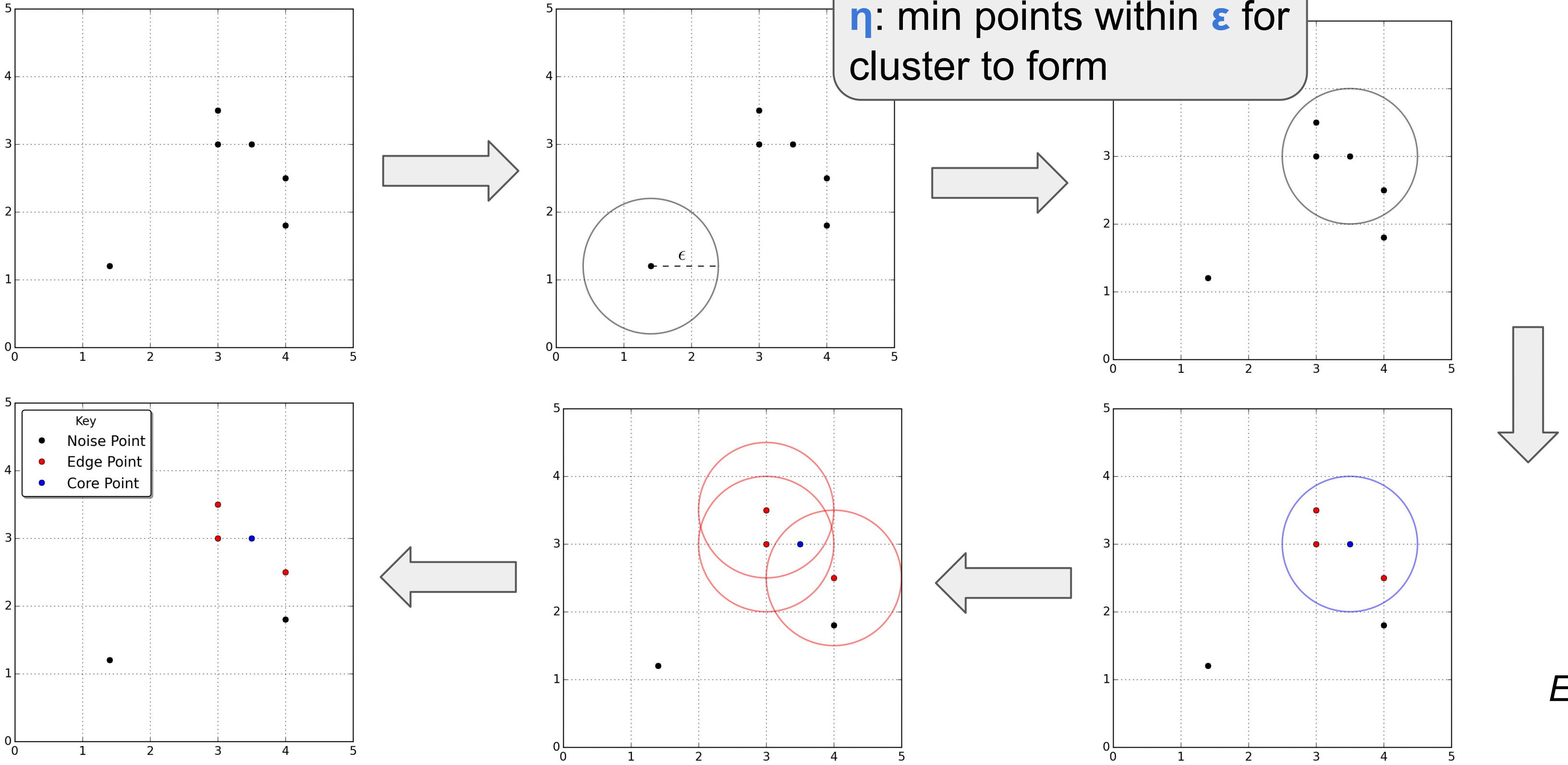




\+ PCA Colour selection (D'Abrusco et al. 2016)

The DBSCAN algorithm

ε: clustering scale length
η: min points within ε for cluster to form



ε=1
η=3

Ester et al. (1996)