Searching for Low-Surface-Brightness Galaxies with the Hyper Suprime-Cam Survey

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Pre 1923: The Realm of the Nebulae

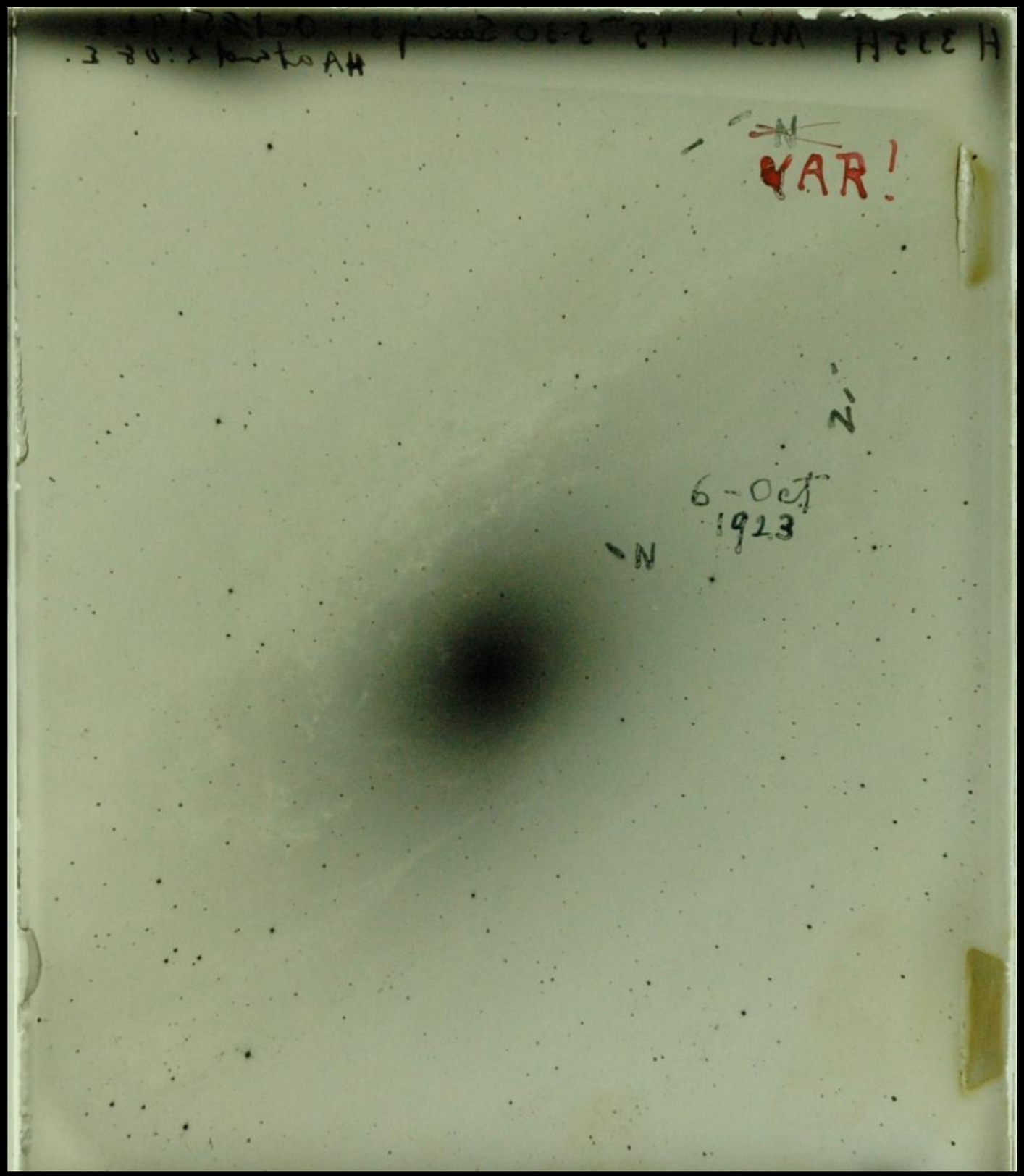


Image credit: Carnegie Observatories

80 years later…

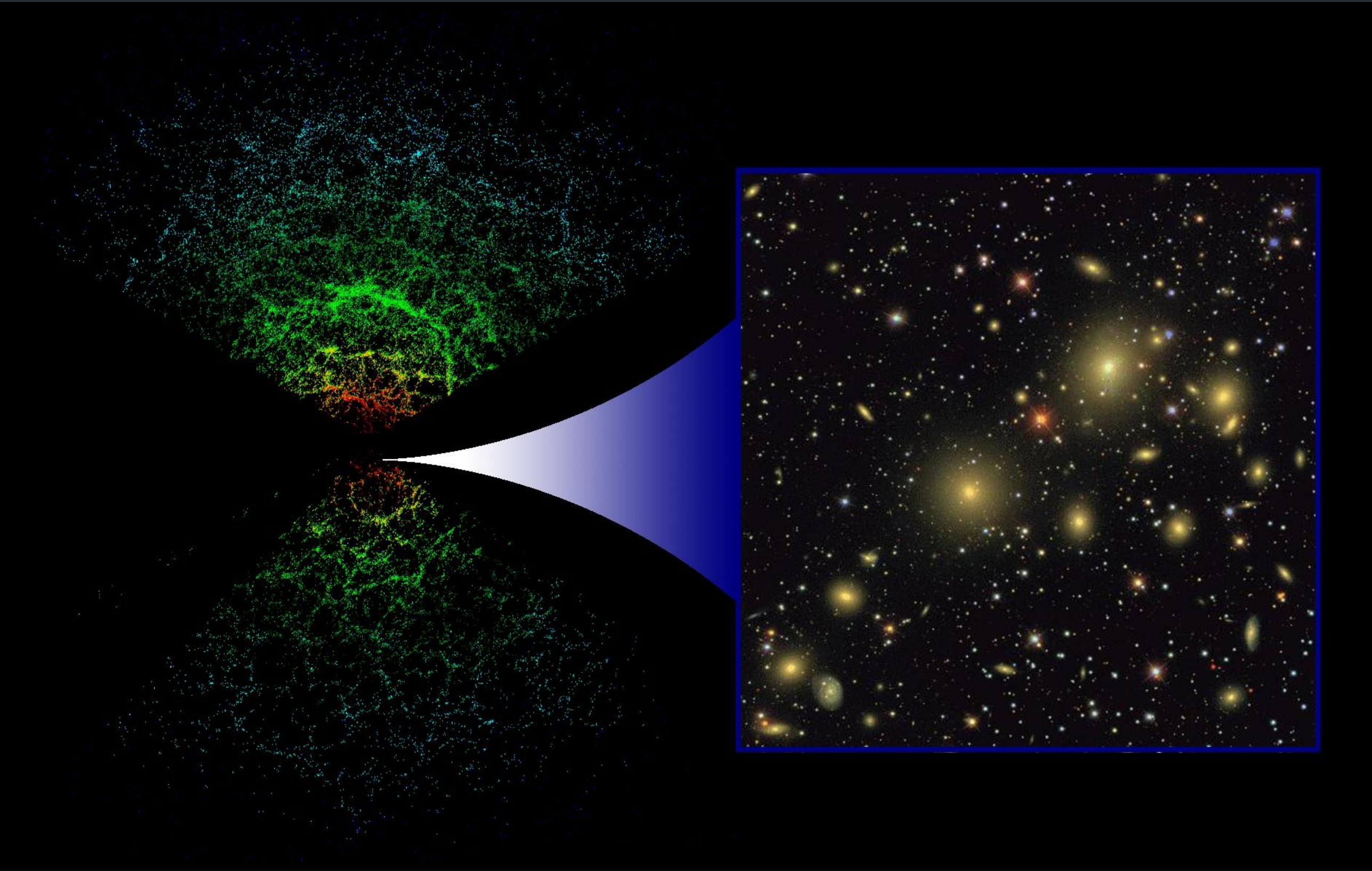
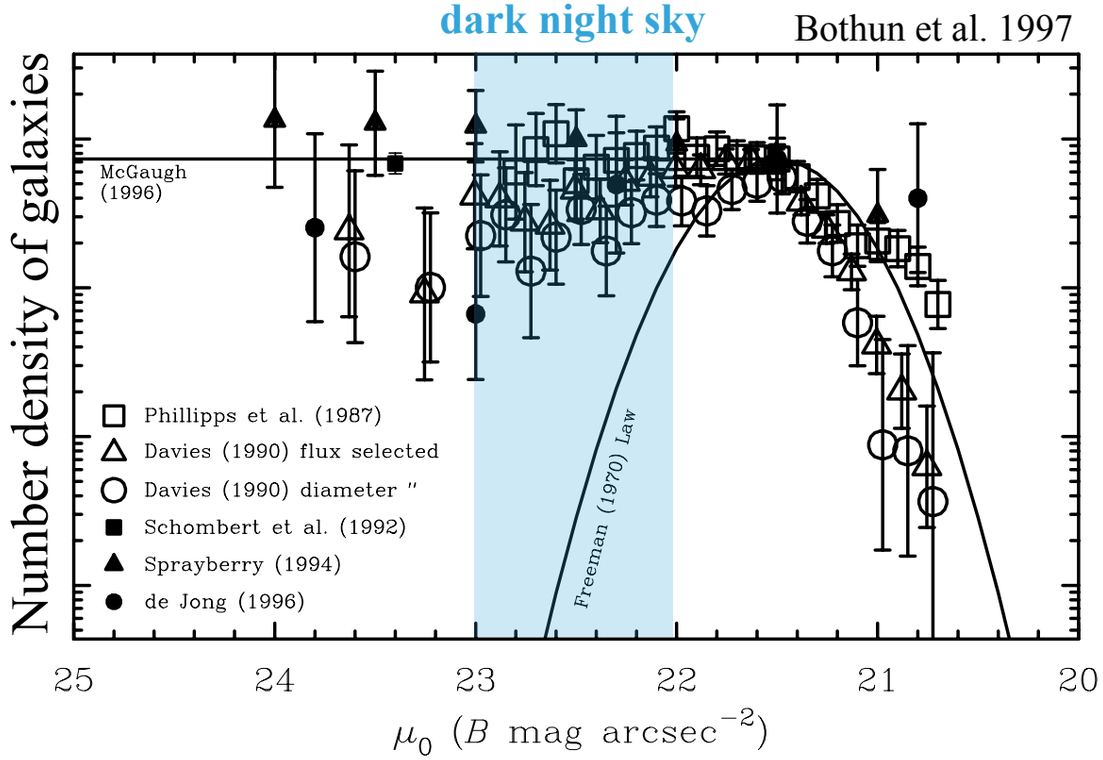


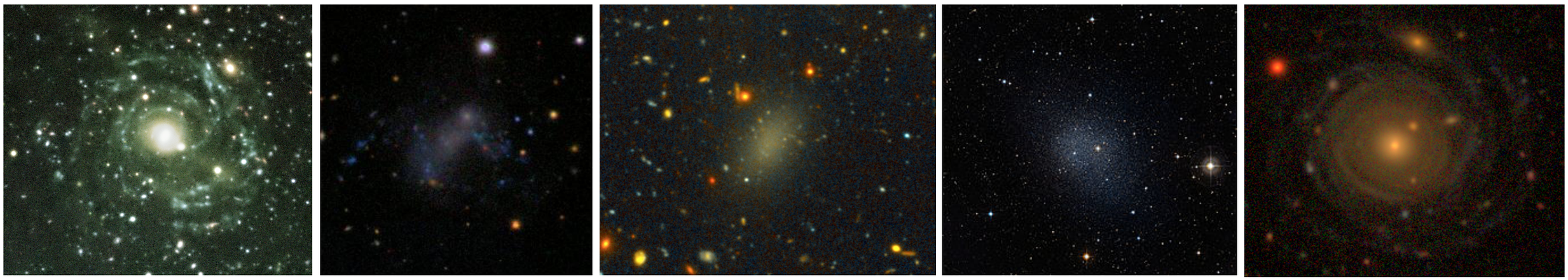
Image credit: SDSS Team (2003), NASA, NSF, DOE

The Hidden Galaxy Population

Low-surface-brightness galaxies (LSBGs)

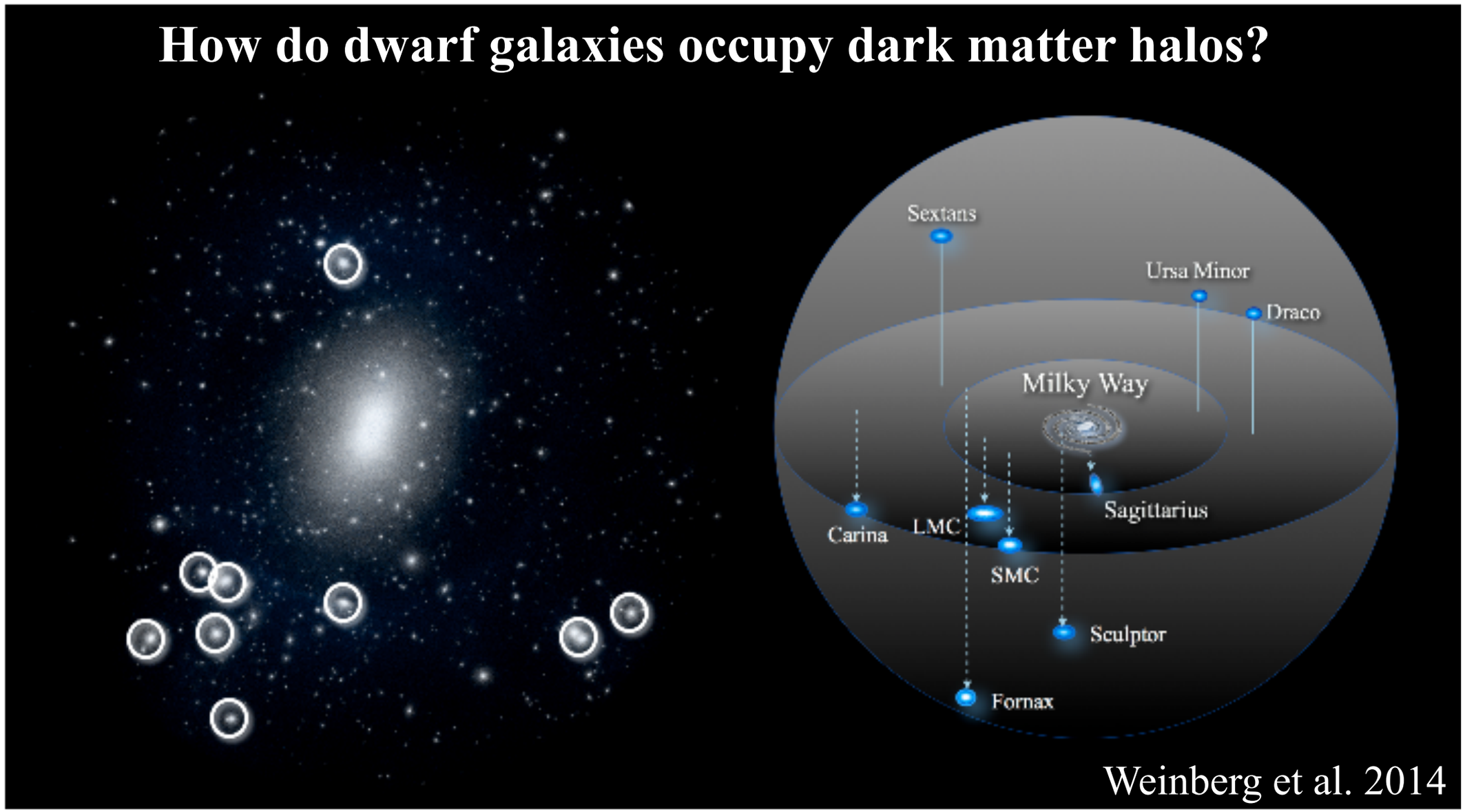
- Surface brightness **fainter than night sky**
- Span **all galaxy types** and environments
- Underrepresented in previous optical surveys





The Hidden Galaxy Population

LSBGs as a testing ground for LCDM…



The Latest Craze: Ultra-Diffuse Galaxies (UDGs)

1 kpc

M33

NGC 205

M31

M32

Fornax

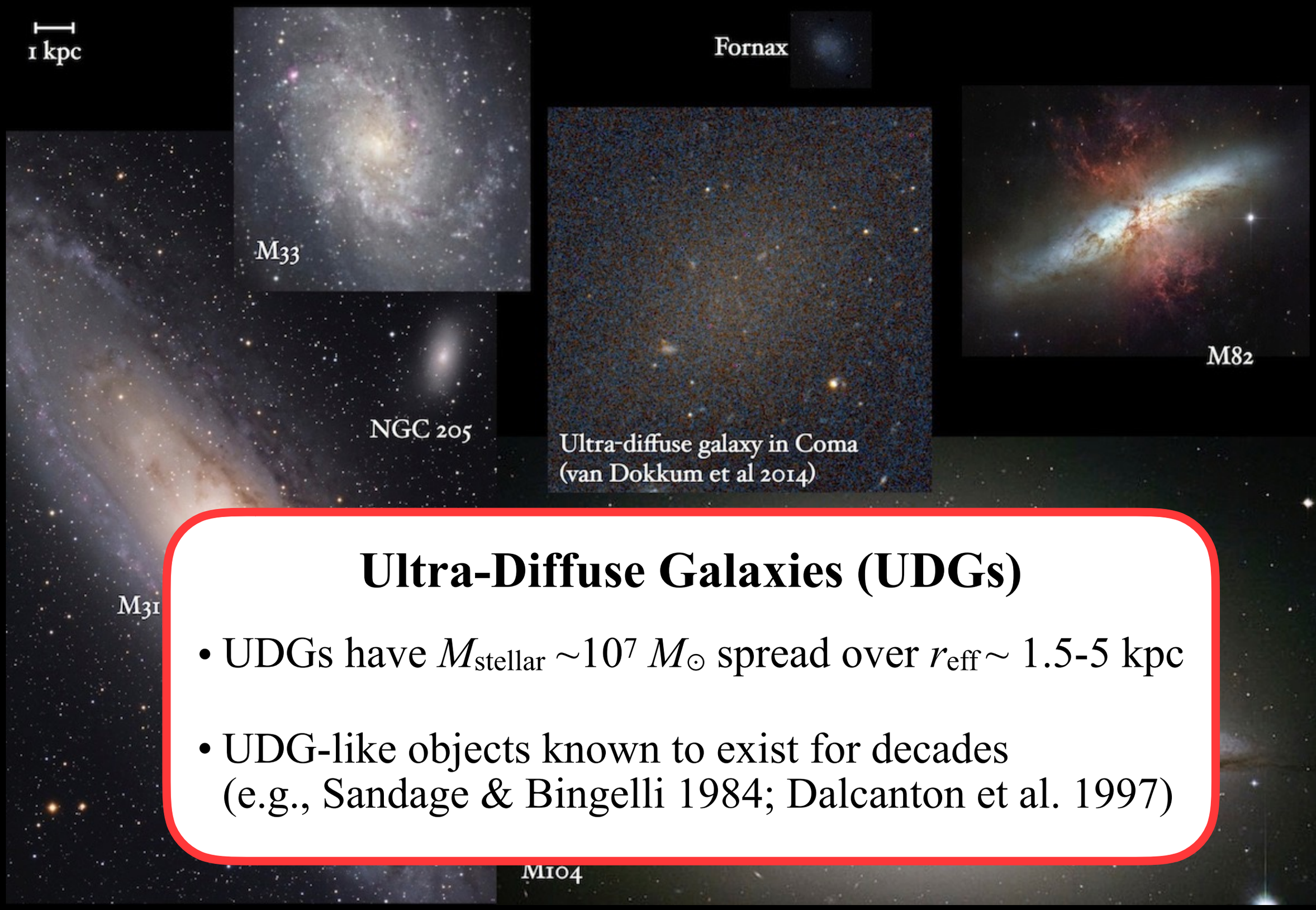
Ultra-diffuse galaxy in Coma
(van Dokkum et al 2014)

M82

M104

Image credit: Pieter van Dokkum

The Latest Craze: Ultra-Diffuse Galaxies (UDGs)



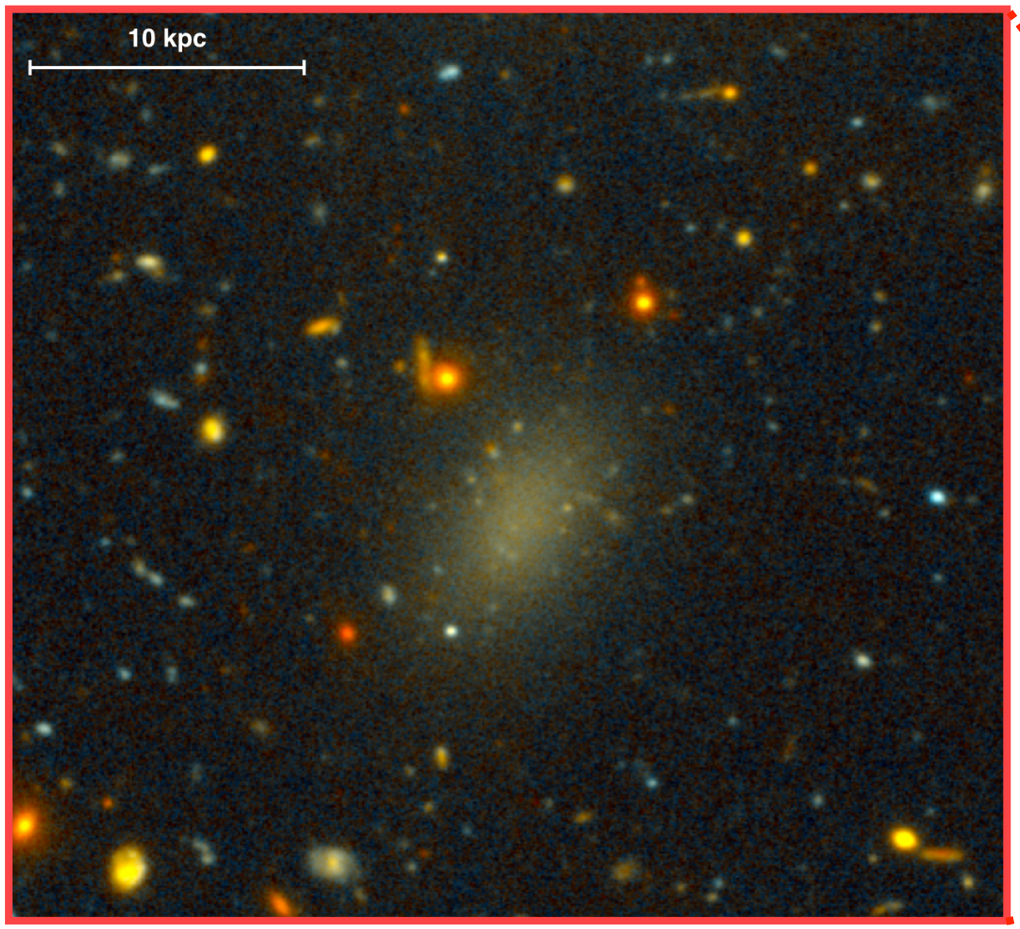
Ultra-Diffuse Galaxies (UDGs)

- UDGs have $M_{\rm stellar} \sim 10^7\ M_\odot$ spread over $r_{\rm eff} \sim$ 1.5-5 kpc

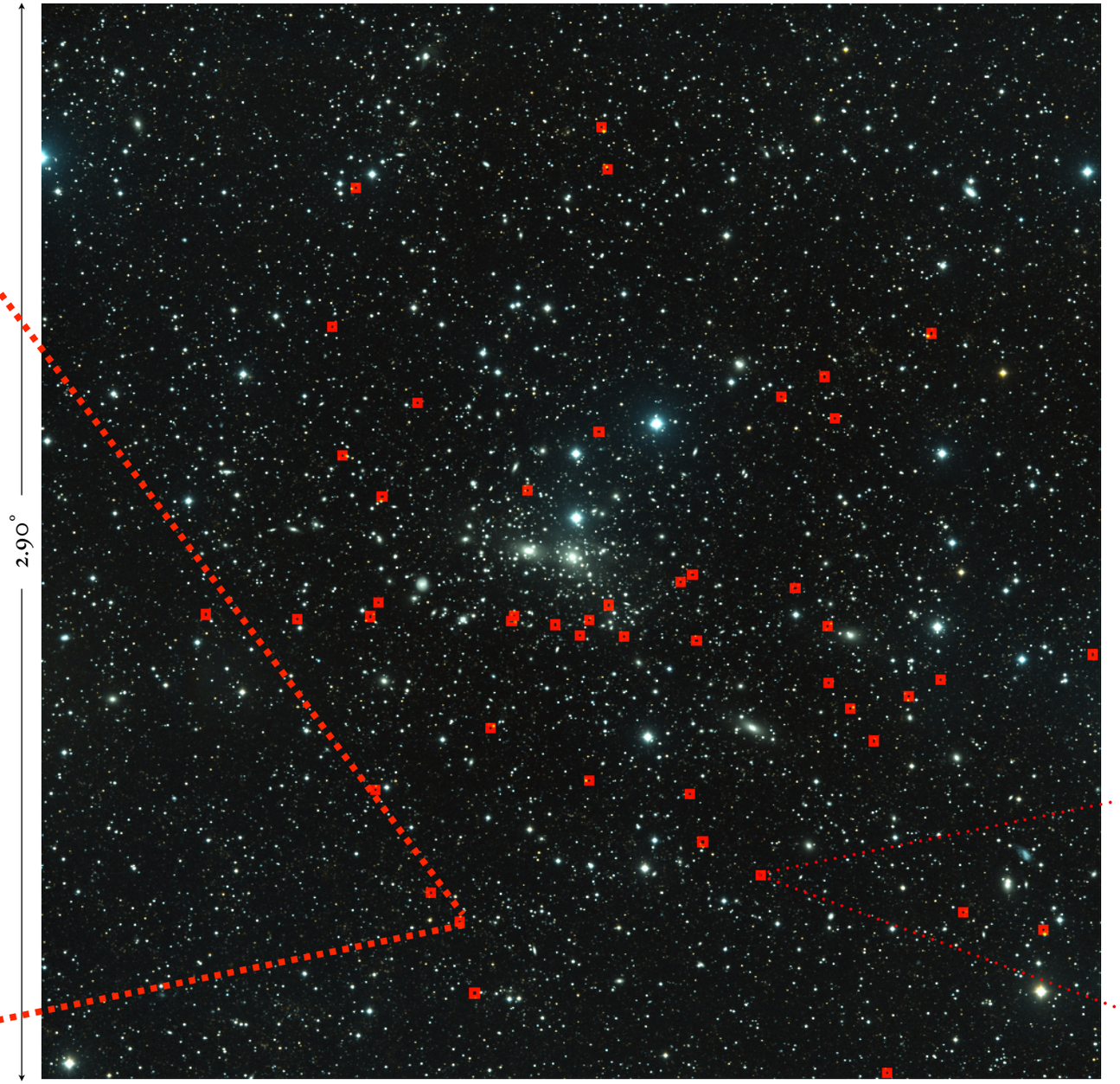
- UDG-like objects known to exist for decades (e.g., Sandage & Bingelli 1984; Dalcanton et al. 1997)

Image credit: Pieter van Dokkum

~1000 UDG candidates in Coma!



Dragonfly 44

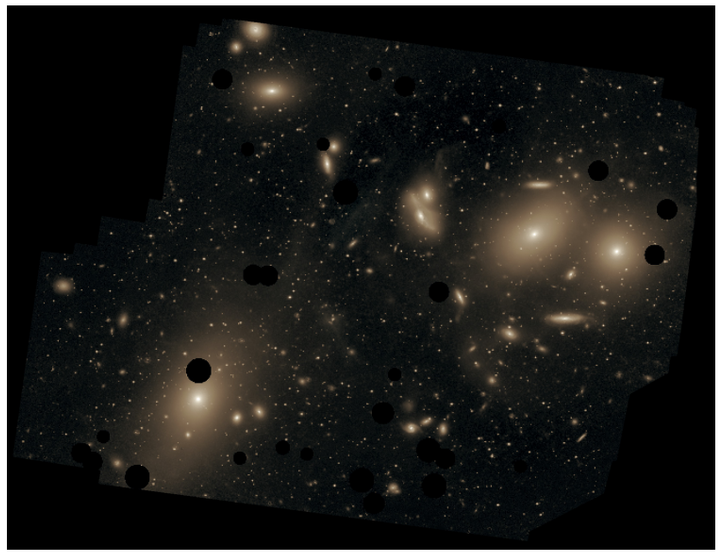


Coma Cluster

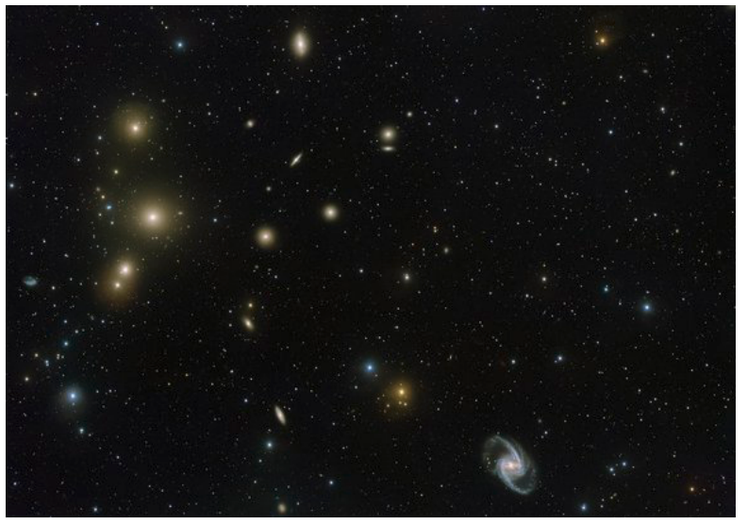
van Dokkum et al. 2015, 2016; Koda et al. 2015

UDGs common in rich clusters

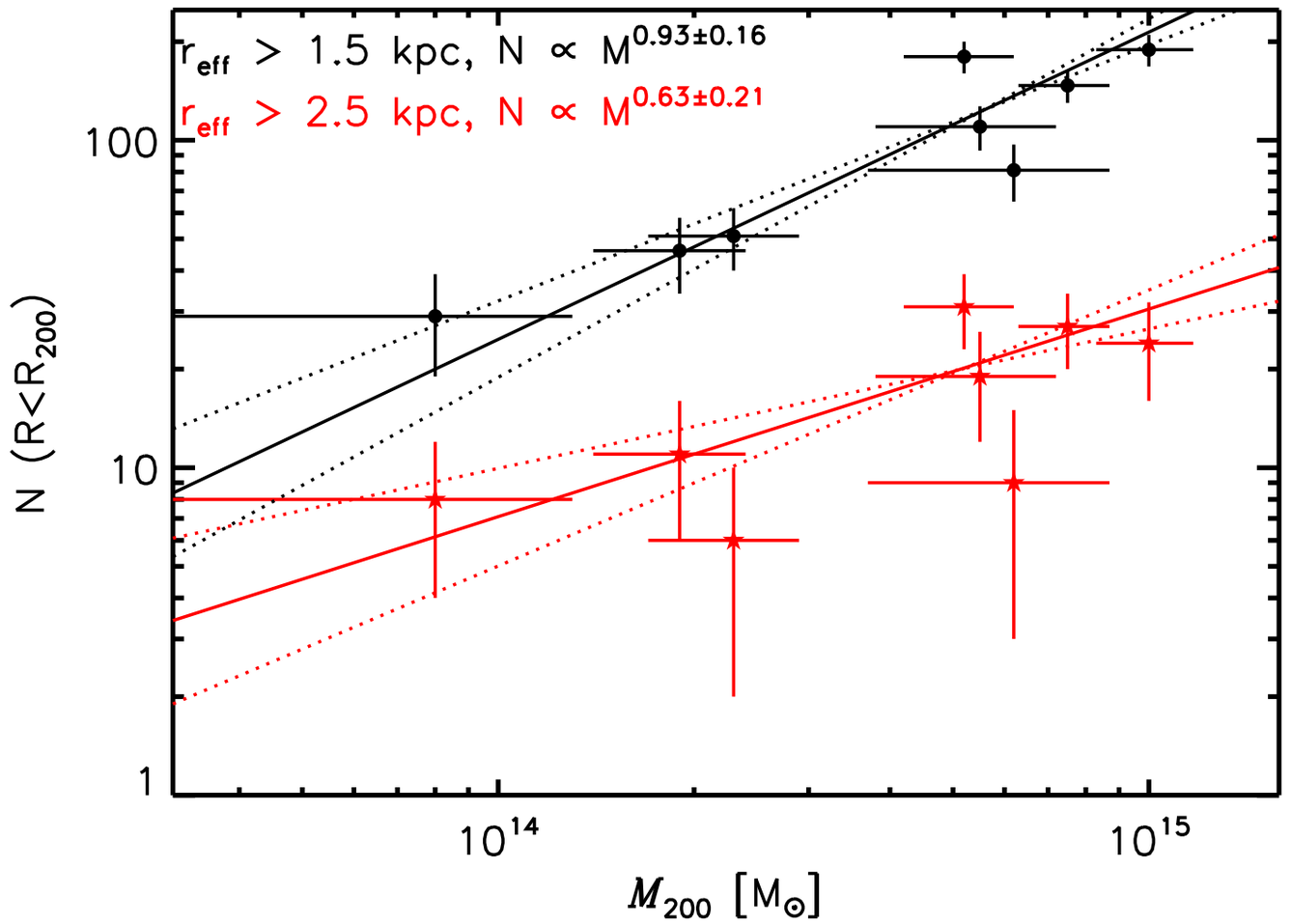
New UDGs also found in….



Virgo
(Mihos et al. 2015)



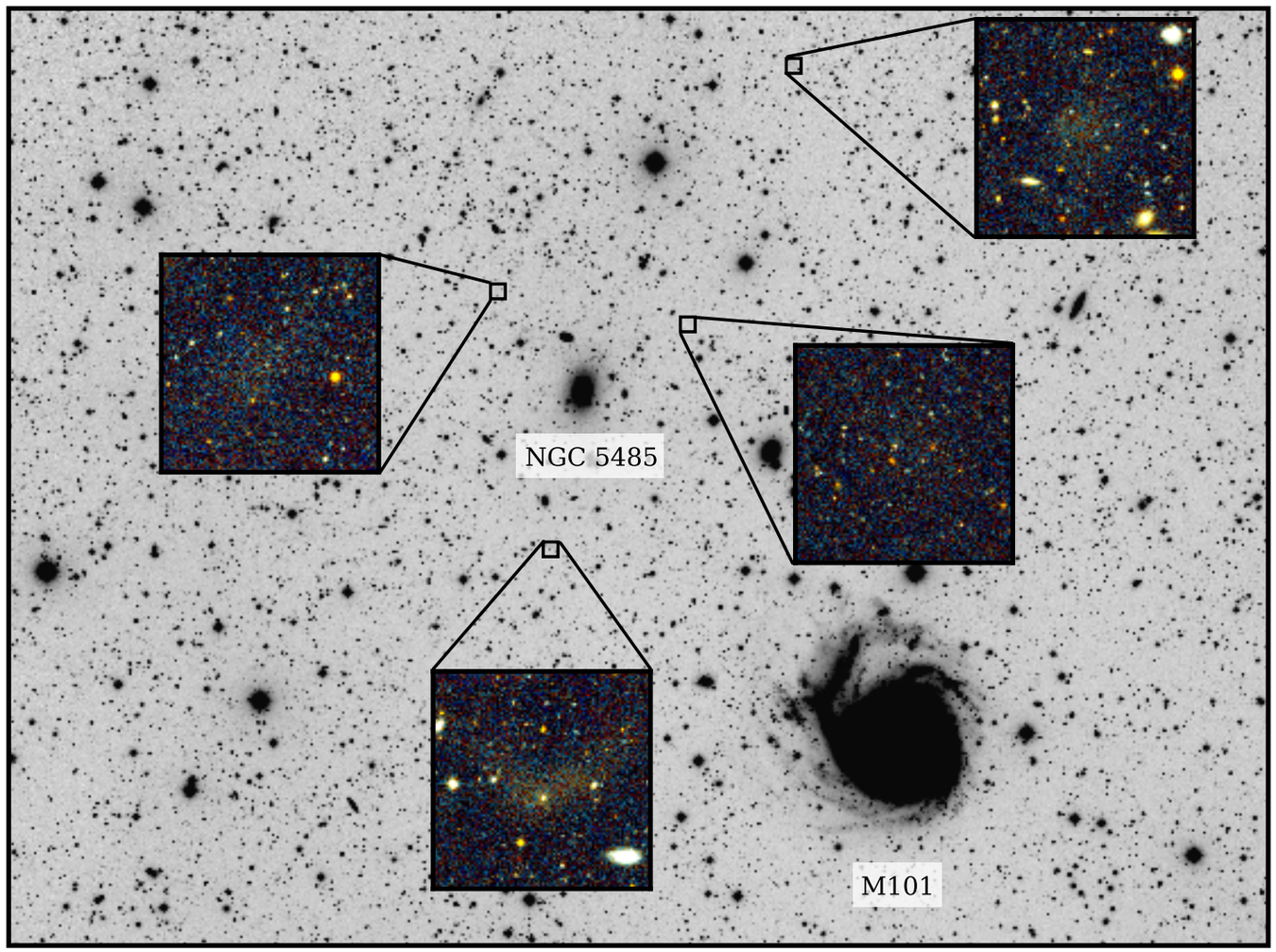
Fornax
(Munoz et al. 2015)



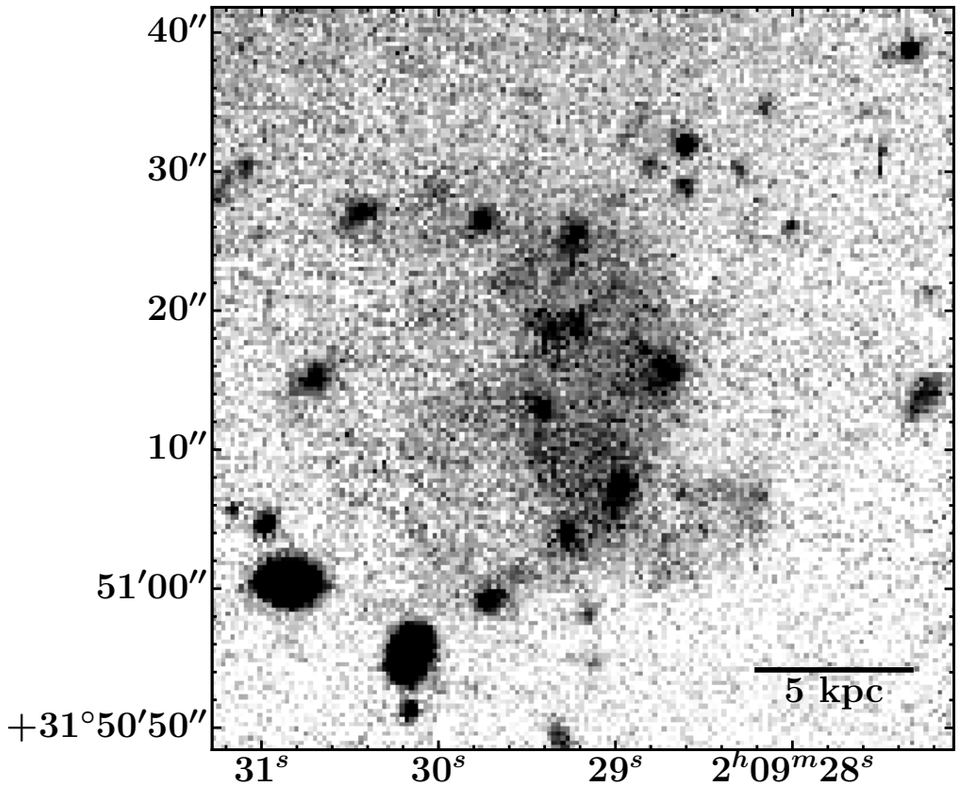
… and 8 low-z clusters:
(van der Burg et al. 2016)

UDGs in groups and the field

New UDGs also found in….



Small groups
(Merritt et al. 2016)



The field
(Leisman et al. 2017)

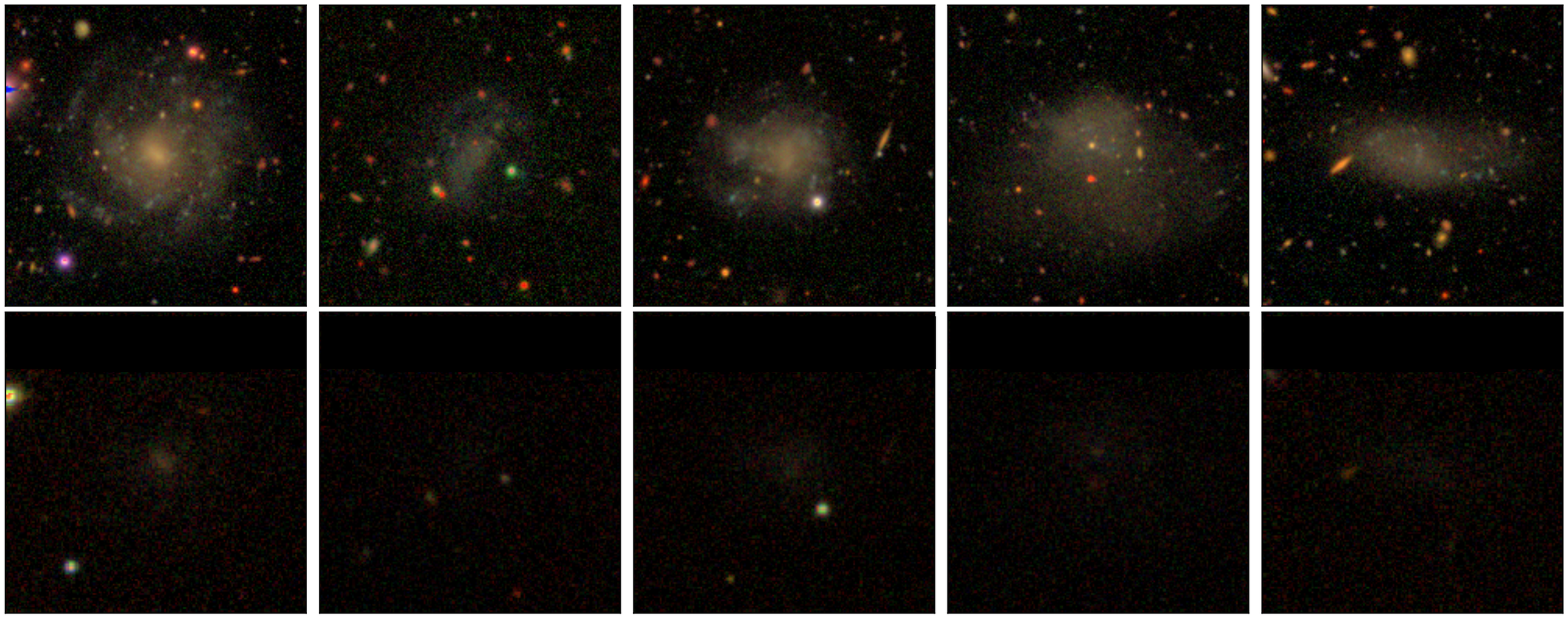
Need deep + wide blind search

Need deep + wide blind search

Ultra-LSB sources in SDSS

Need deep + wide blind search

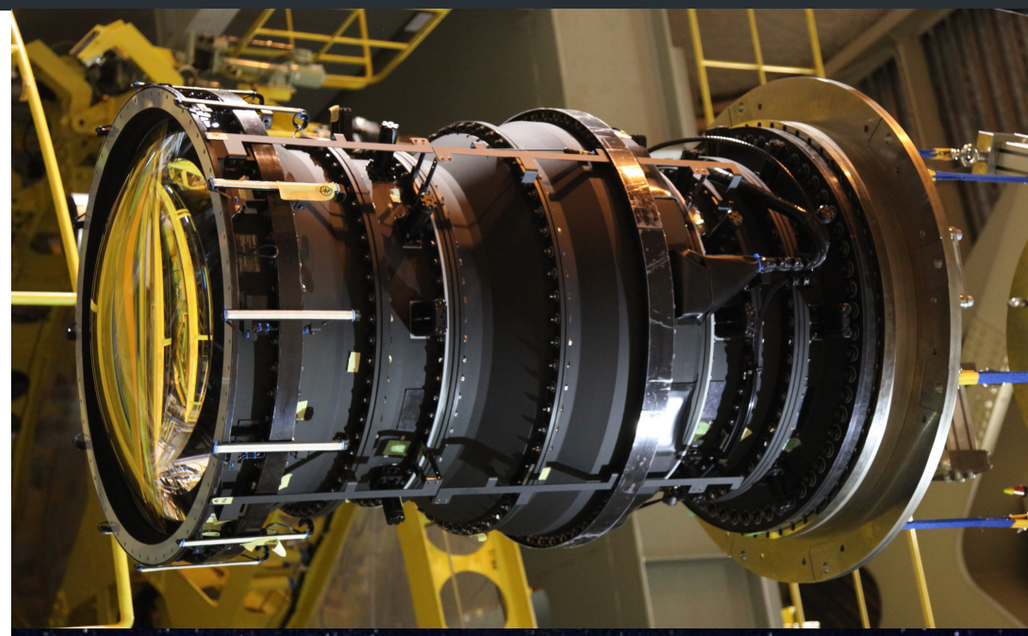
A new view with the Hyper Suprime-Cam (HSC)



Ultra-LSB sources in SDSS

The Hyper Suprime-Cam Subaru Strategic Program

HSC Collaboration Meeting Kavli IPMU, Kashiwa, Japan (2016)



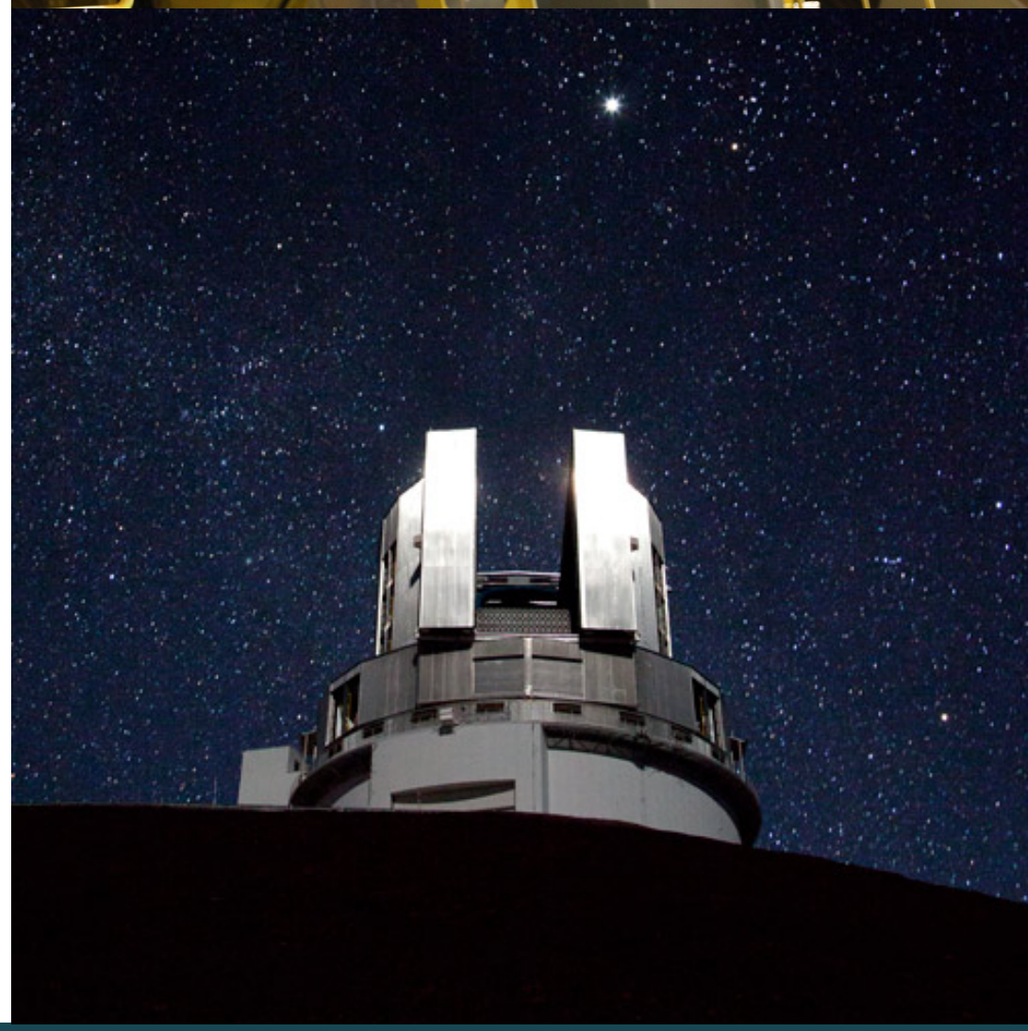


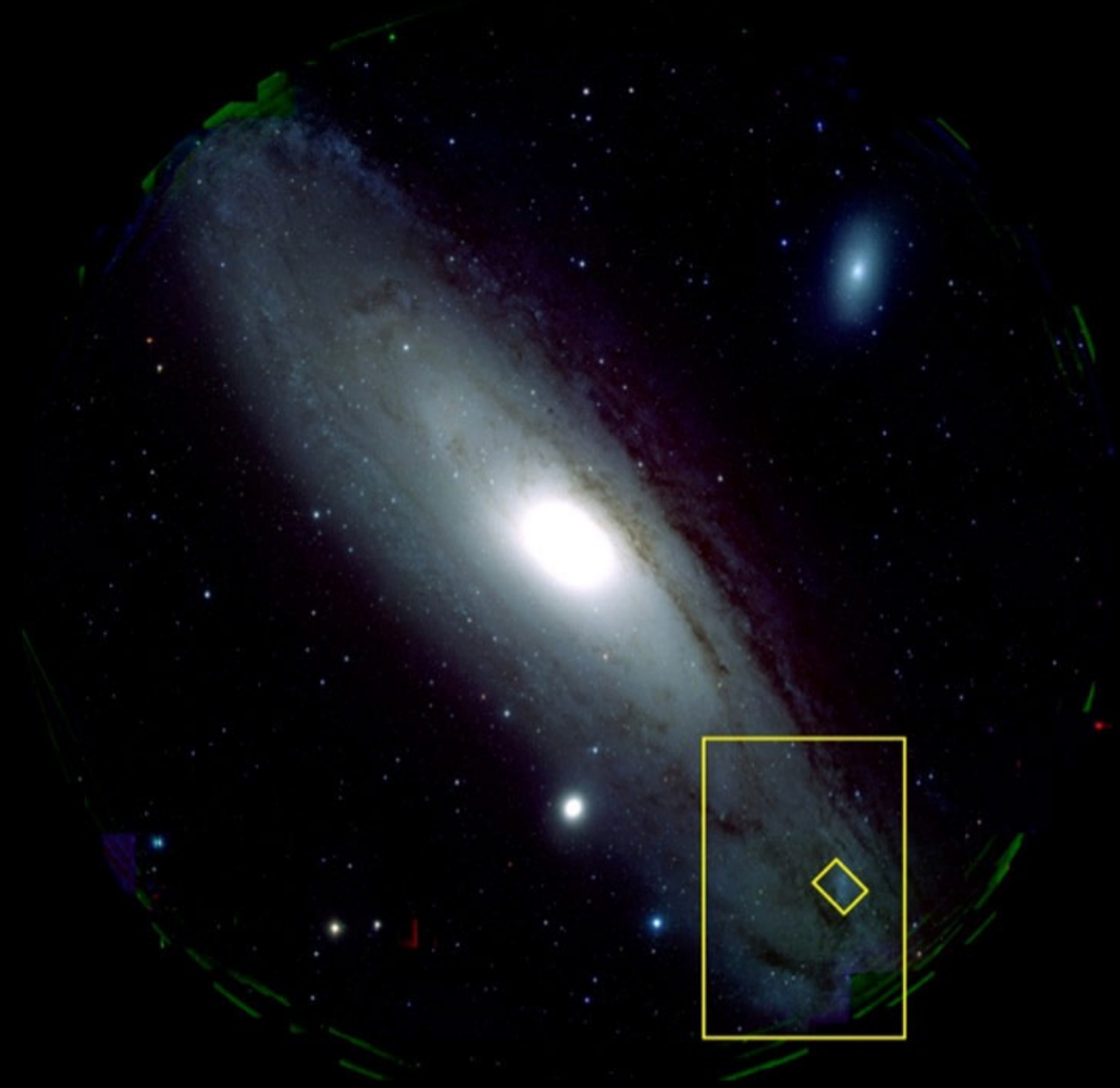
Image credits: NAOJ

Hyper Suprime-Cam

Typical Apparent Diameter of the Moon (0.5 degrees)

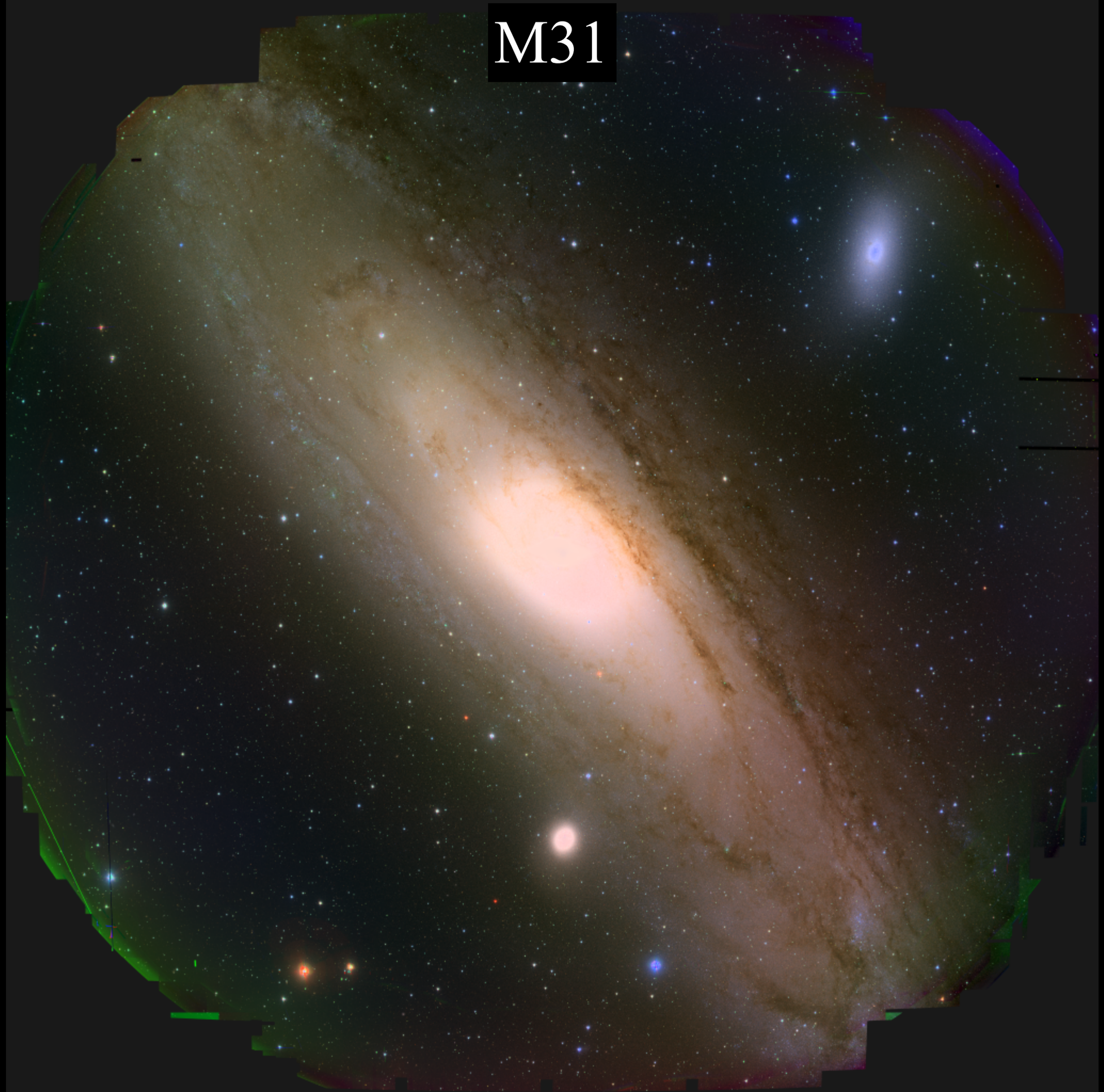
Suprime-Cam
First Light Release
January 1999

Suprime-Cam
Image Release
September 2001



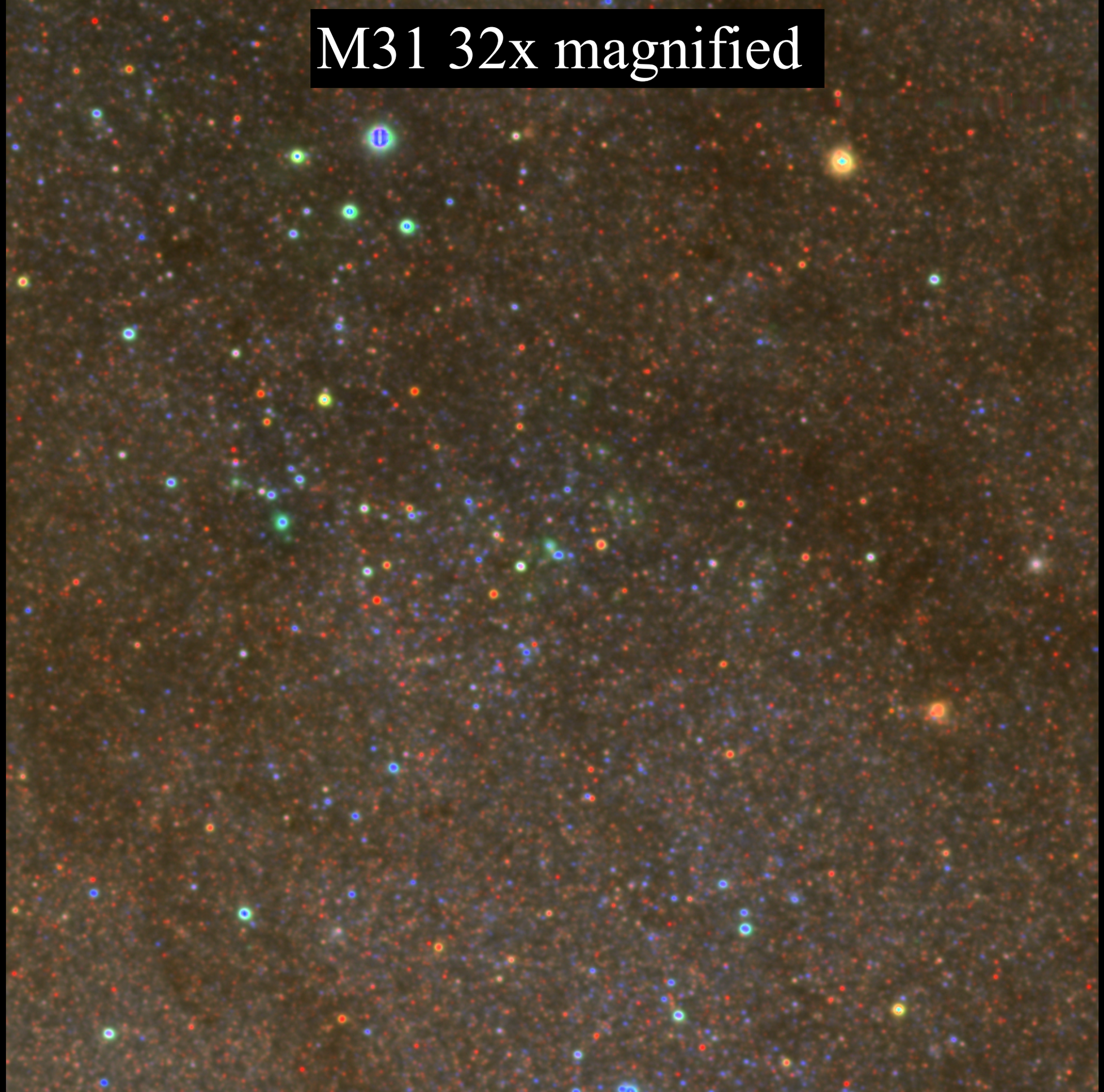
Hyper Suprime-Cam
Image Release
July 2013

Image credit: NAOJ

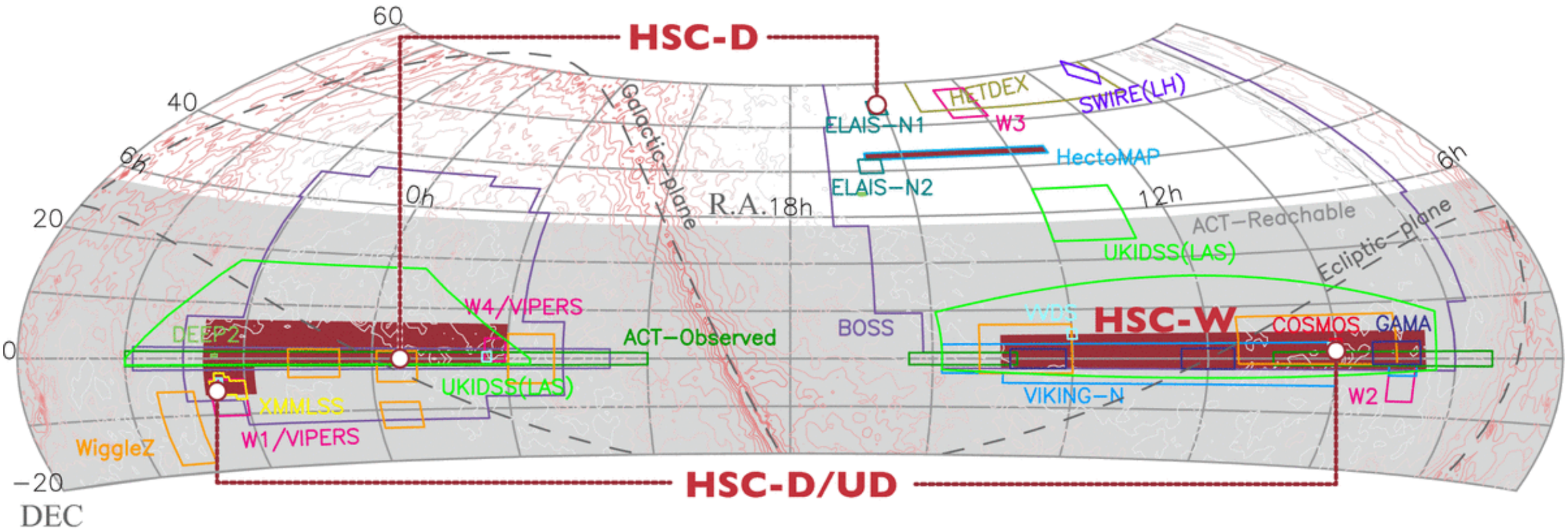

M31

M31 2x magnified

M31 8x magnified


M31 32x magnified

Hyper Suprime-Cam Survey



5 years, 300 Nights

	Wide	Deep	Ultra-Deep
Area	1400 deg^2	27 deg^2	3.5 deg^2
Filters	*grizy*	*grizy*+2NBs	*grizy*+2NBs
Depth (*i*-band)	25.9	26.8	27.4

Figure credit: A. Nishizawa

Hyper Suprime-Cam Survey

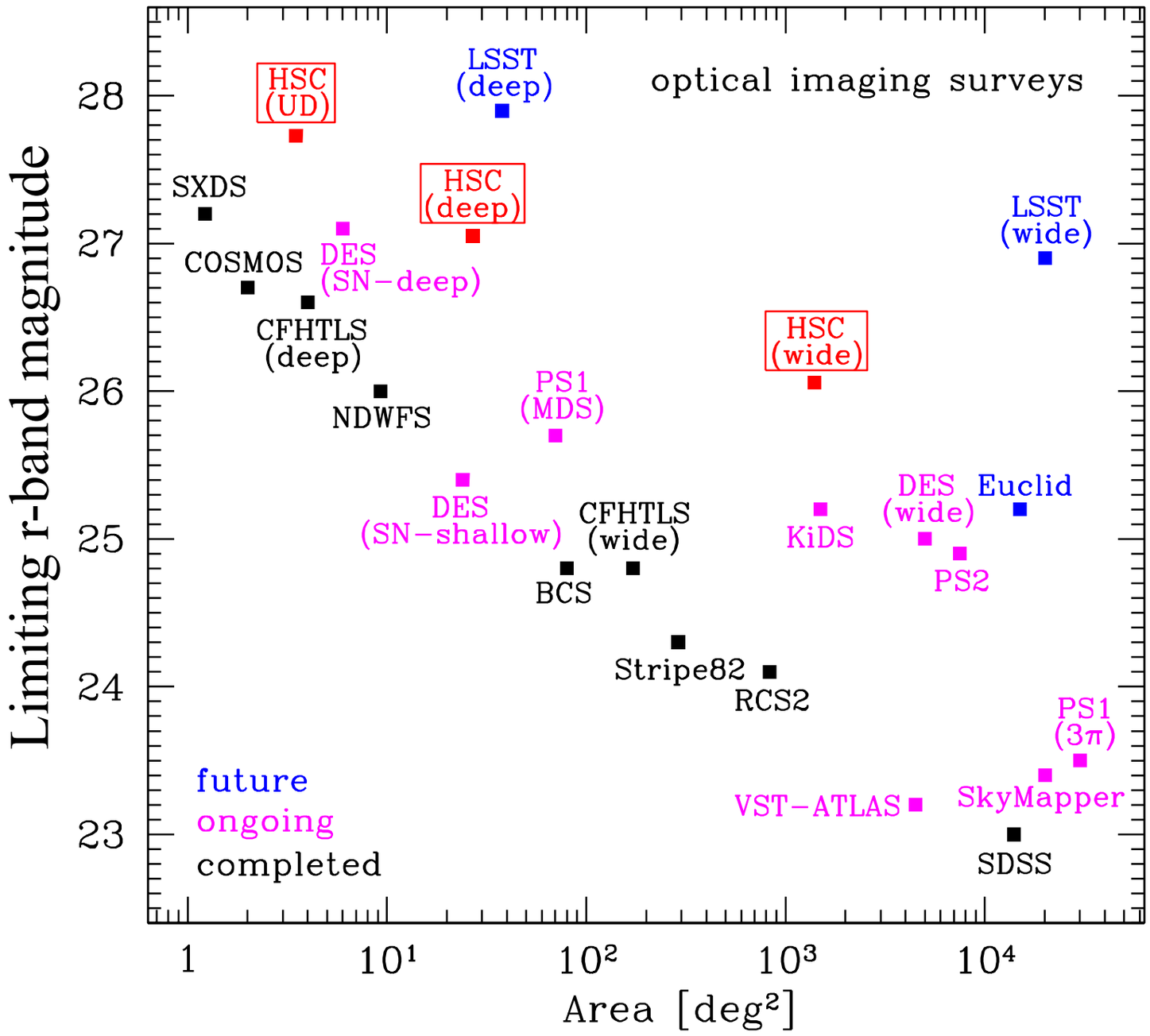
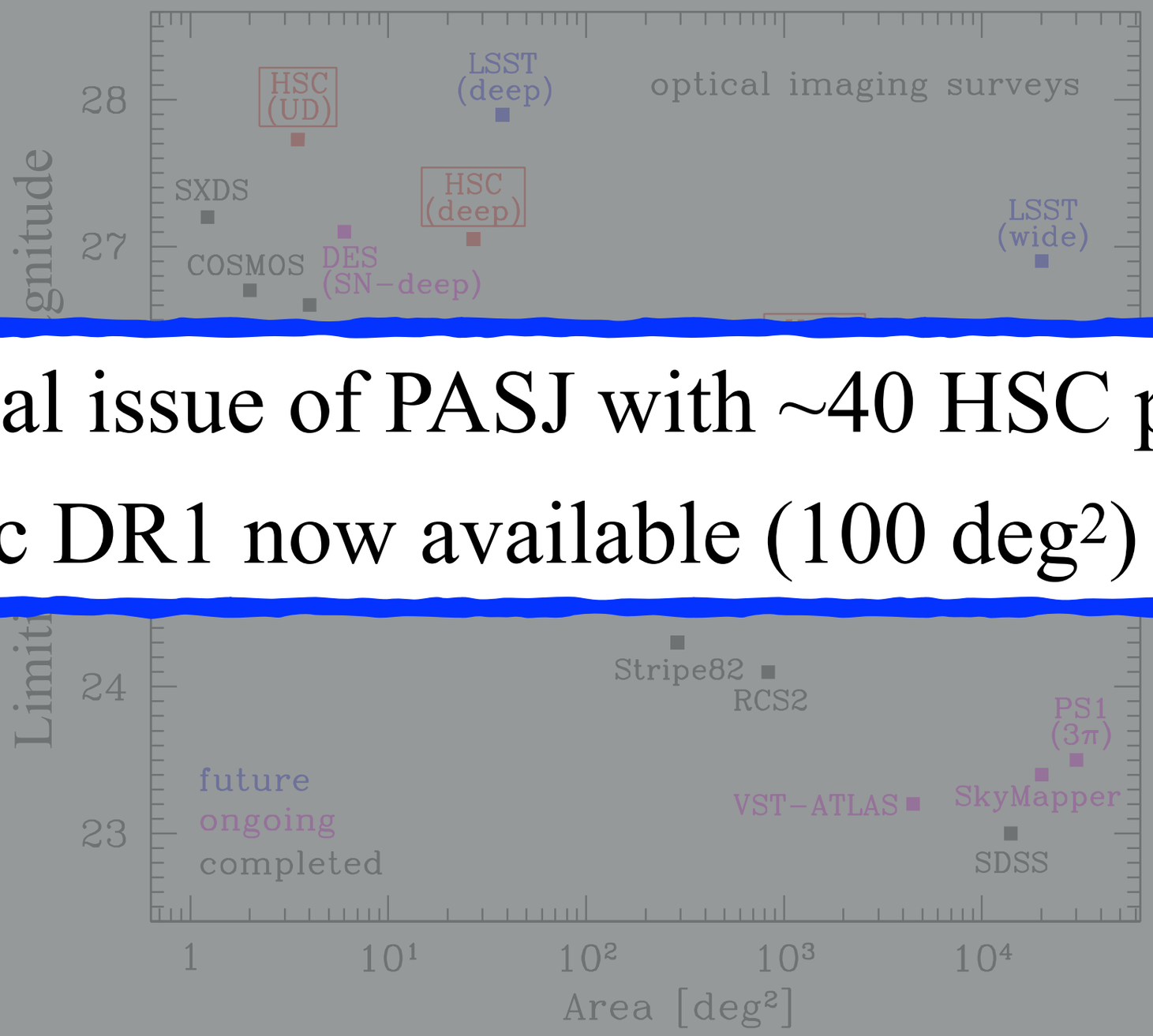


Figure credit: HSC Collaboration (2012)

Hyper Suprime-Cam Survey

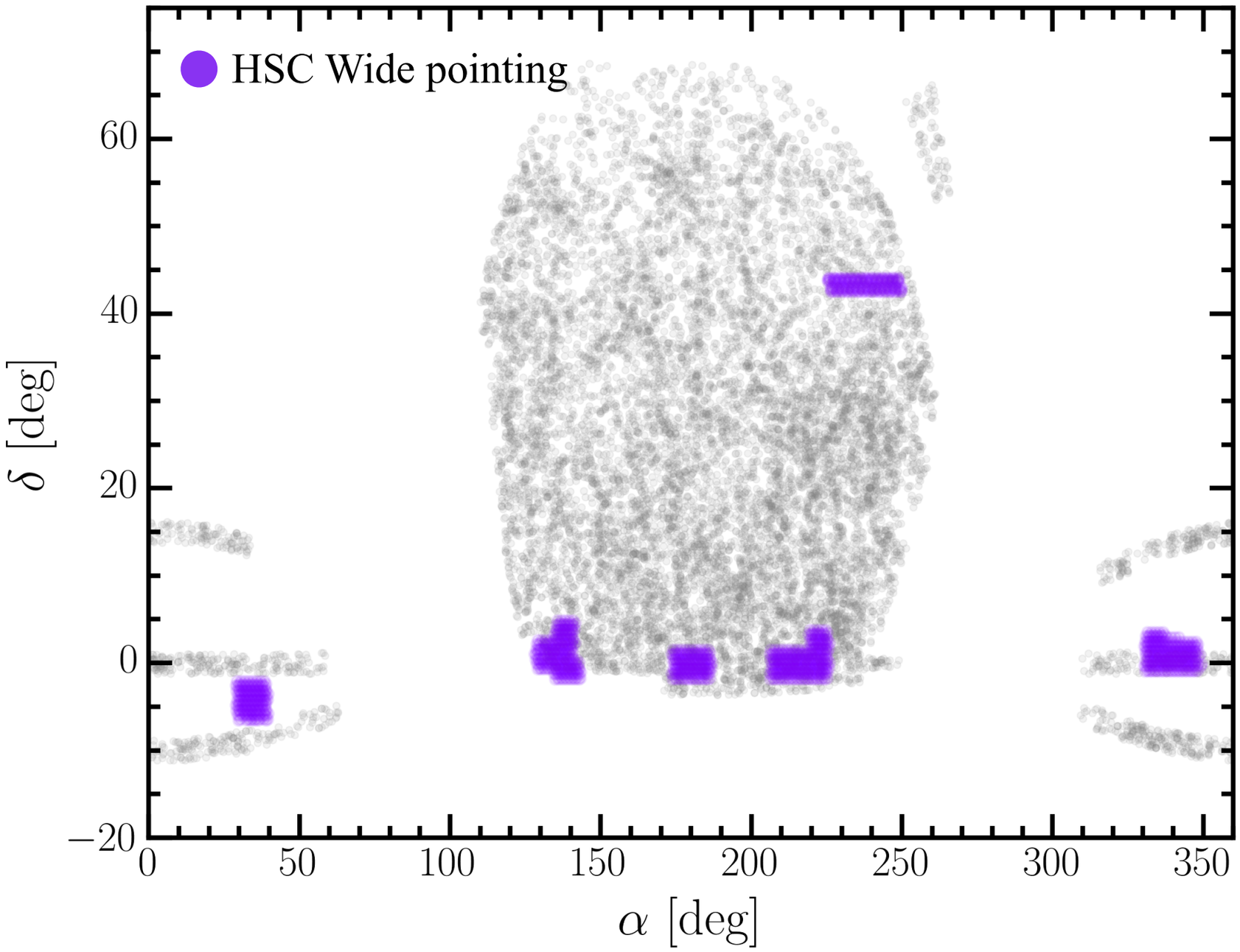


Special issue of PASJ with ~40 HSC papers

Public DR1 now available (100 deg²) !

Figure credit: HSC Collaboration (2012)

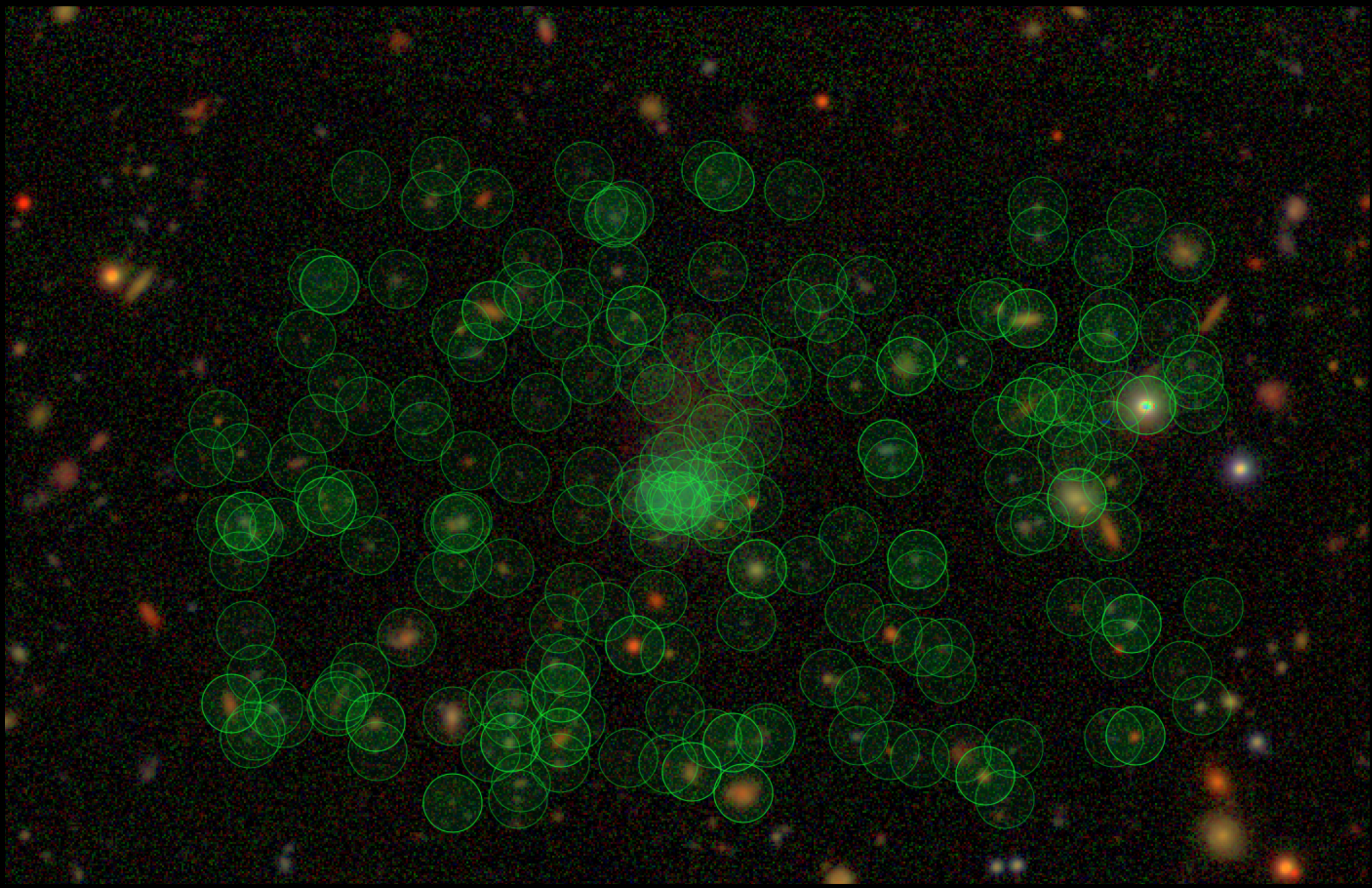
Our search for LSBGs



- Carry out search in HSC **Wide** layer
- **~200 deg²** with full Wider layer depth in *gri*

Search using HSC catalog?

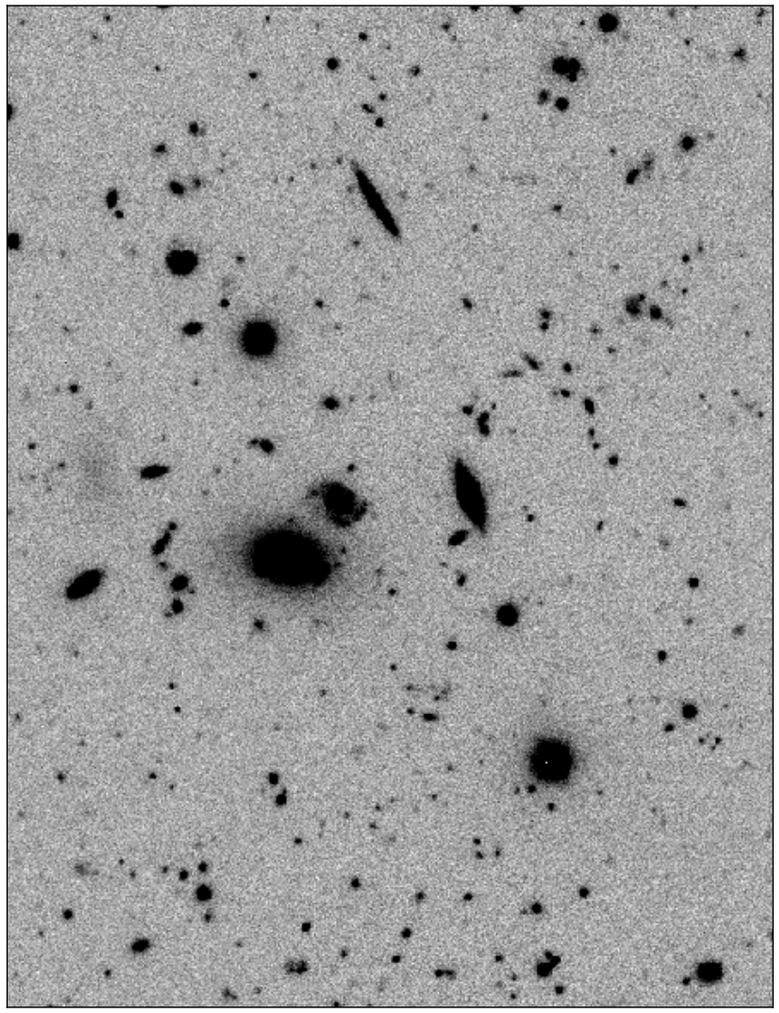
Galaxy Shredding



LSBG Detection Pipeline

LSBG Detection Pipeline: Source Extraction

Original Image



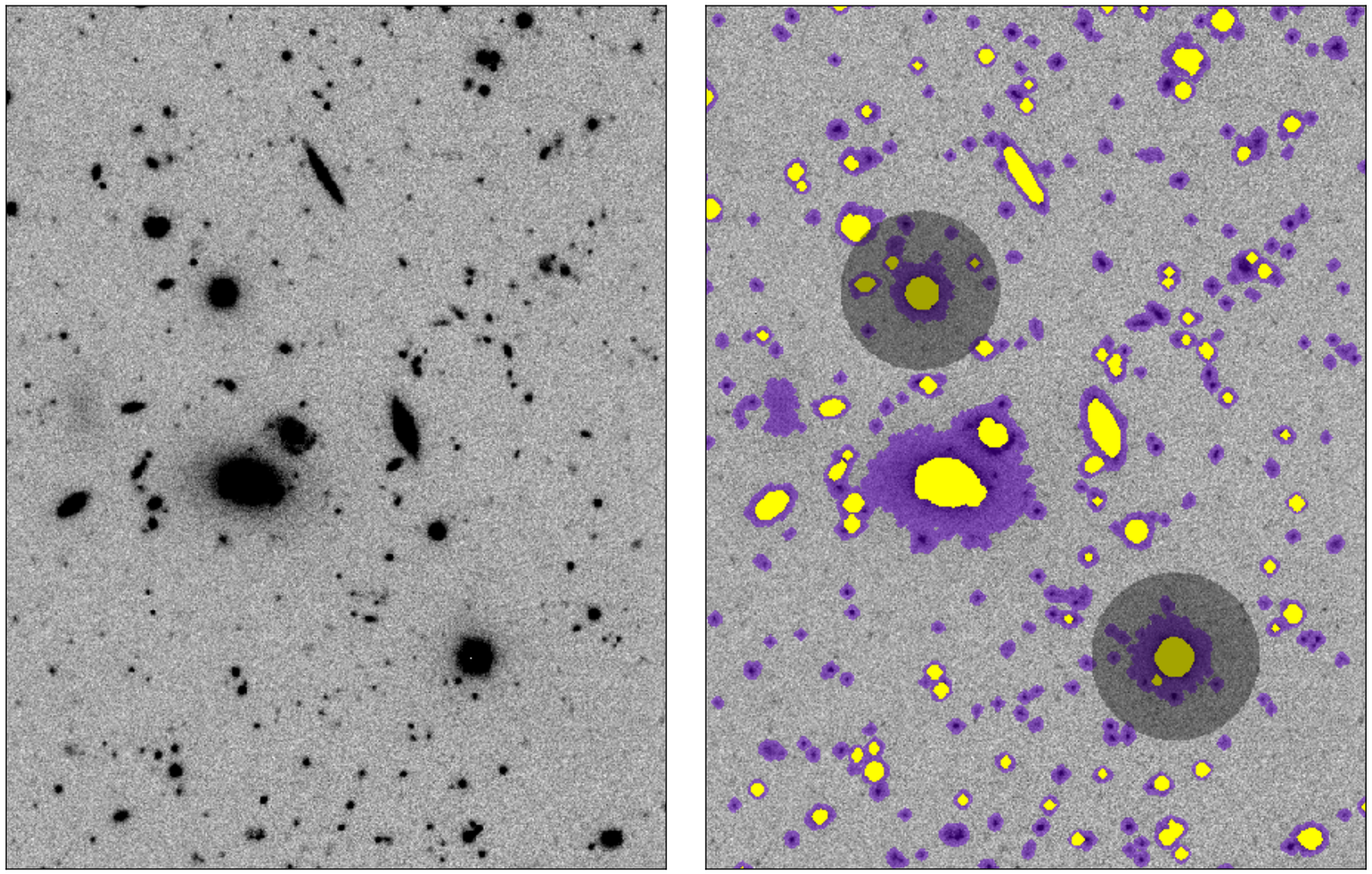
Source extraction in two steps:

- Initial image processing with LSST codebase: http://dm.lsst.org
- Final source detection with *SExtractor*

LSBG Detection Pipeline: Source Extraction

Original Image

Step 1

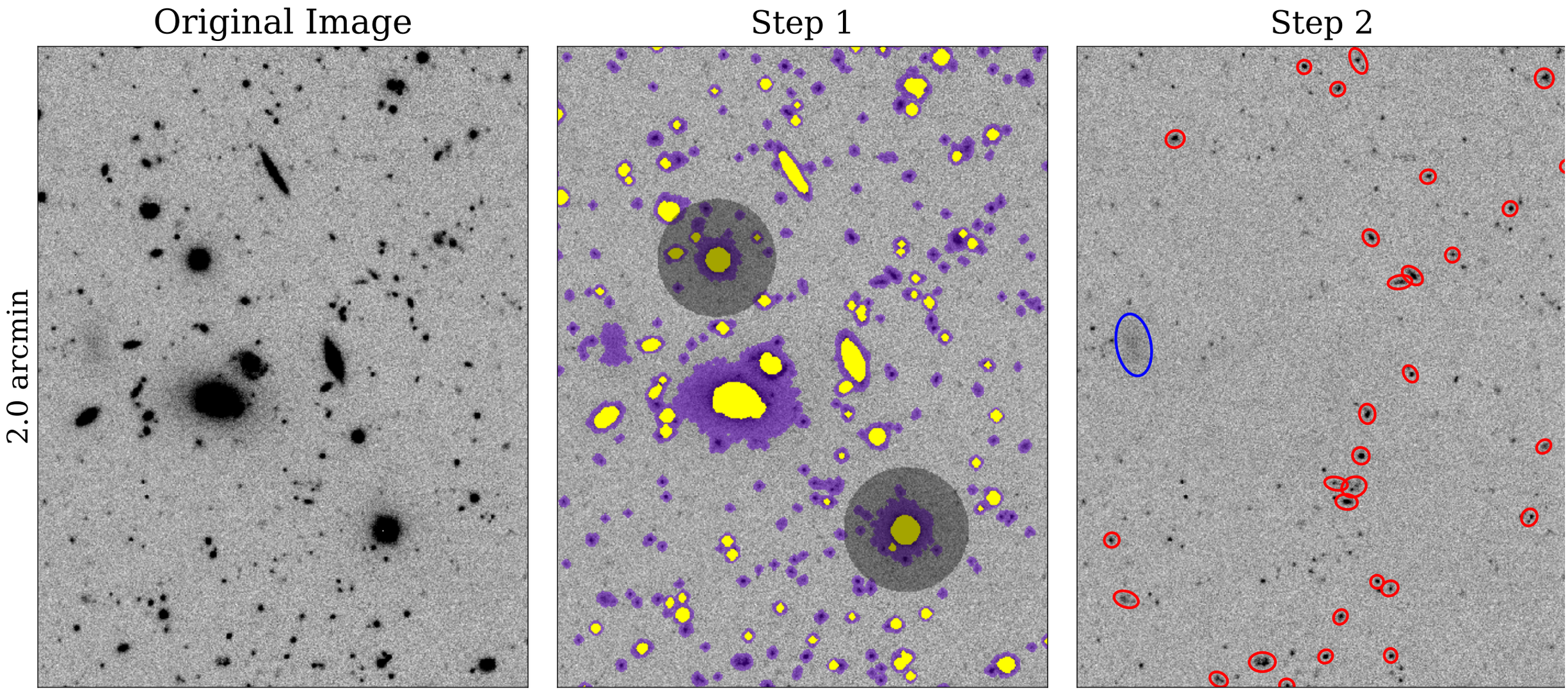


Low- & high-threshold footprints

Source extraction in two steps:

- Initial image processing with LSST codebase: http://dm.lsst.org
- Final source detection with *SExtractor*

LSBG Detection Pipeline: Source Extraction



Source extraction in two steps:

- Initial image processing with LSST codebase: http://dm.lsst.org
- Final source detection with *SExtractor*

Greco et al. 2017, ApJ submitted

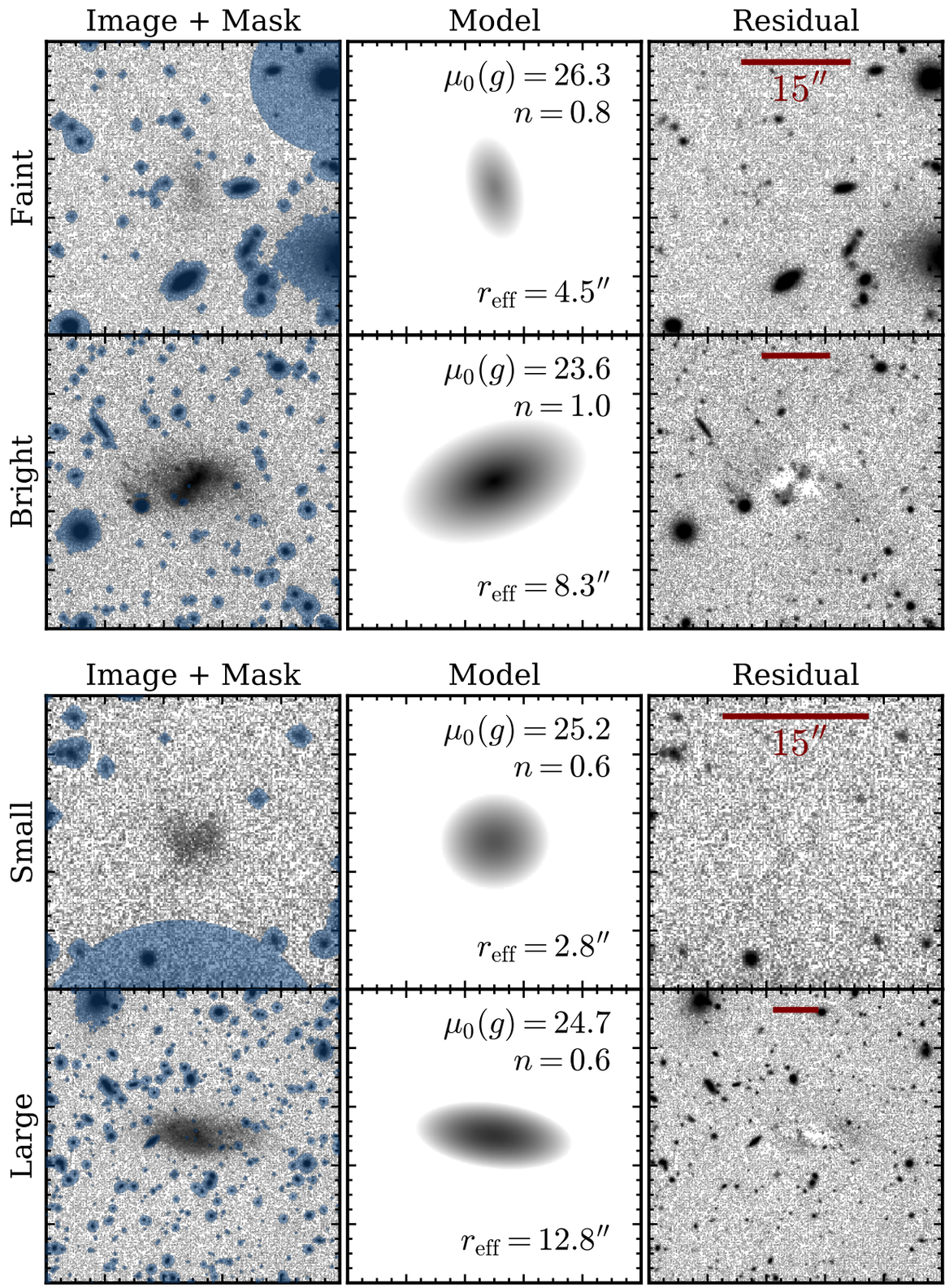
LSBG Detection Pipeline: Galaxy Modeling

Our LSBG definition:

$\bar{\mu}_{\rm eff}(g) > 24.3$ mag arcsec^{-2}

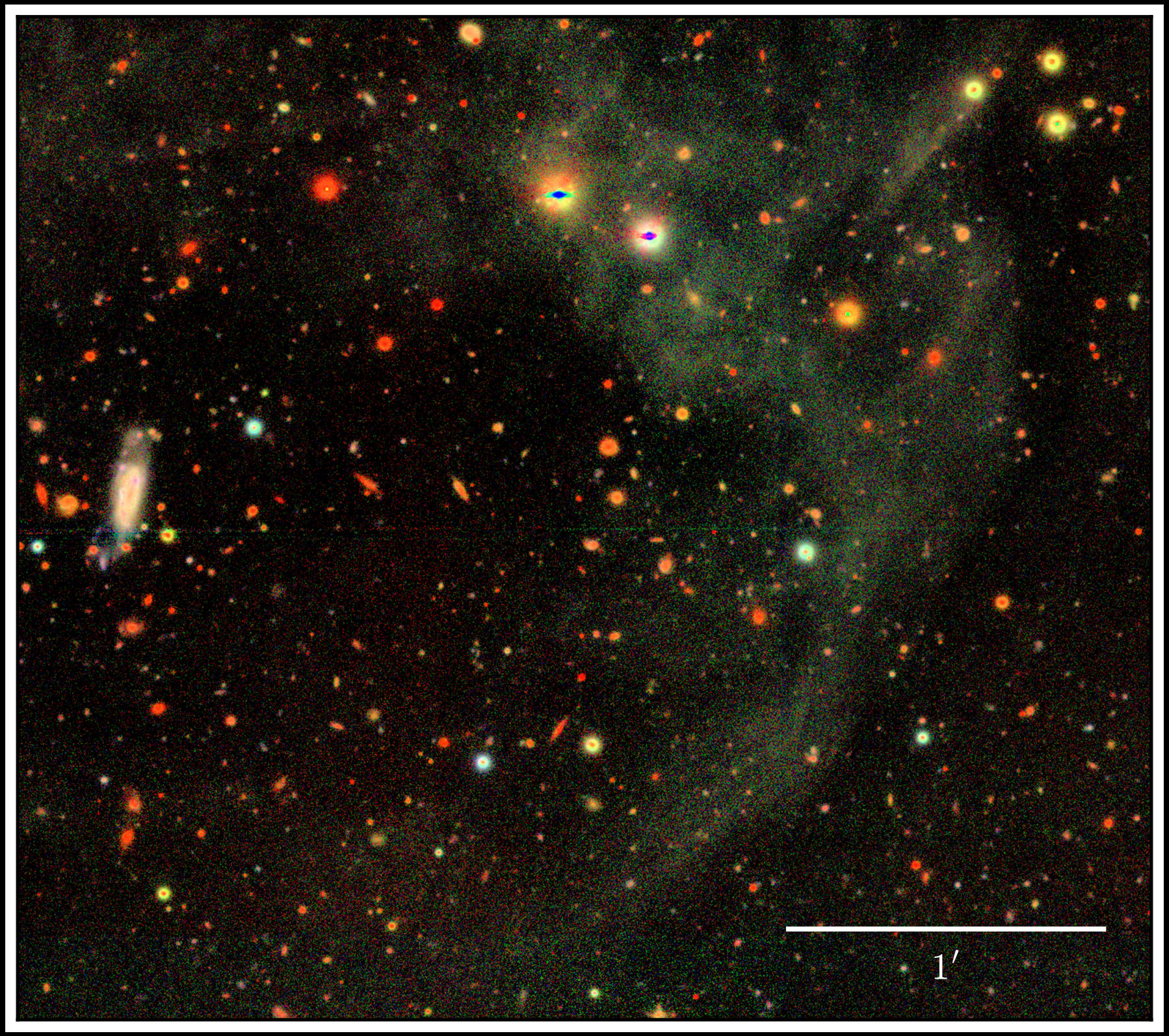
$r_{\rm eff} > 2.5''$

- Model LSBG candidates as single-component Sersic functions
- Make selection on best-fit parameters
- Visually inspect remaining candidates
- Final sample size: **781 LSBGs**



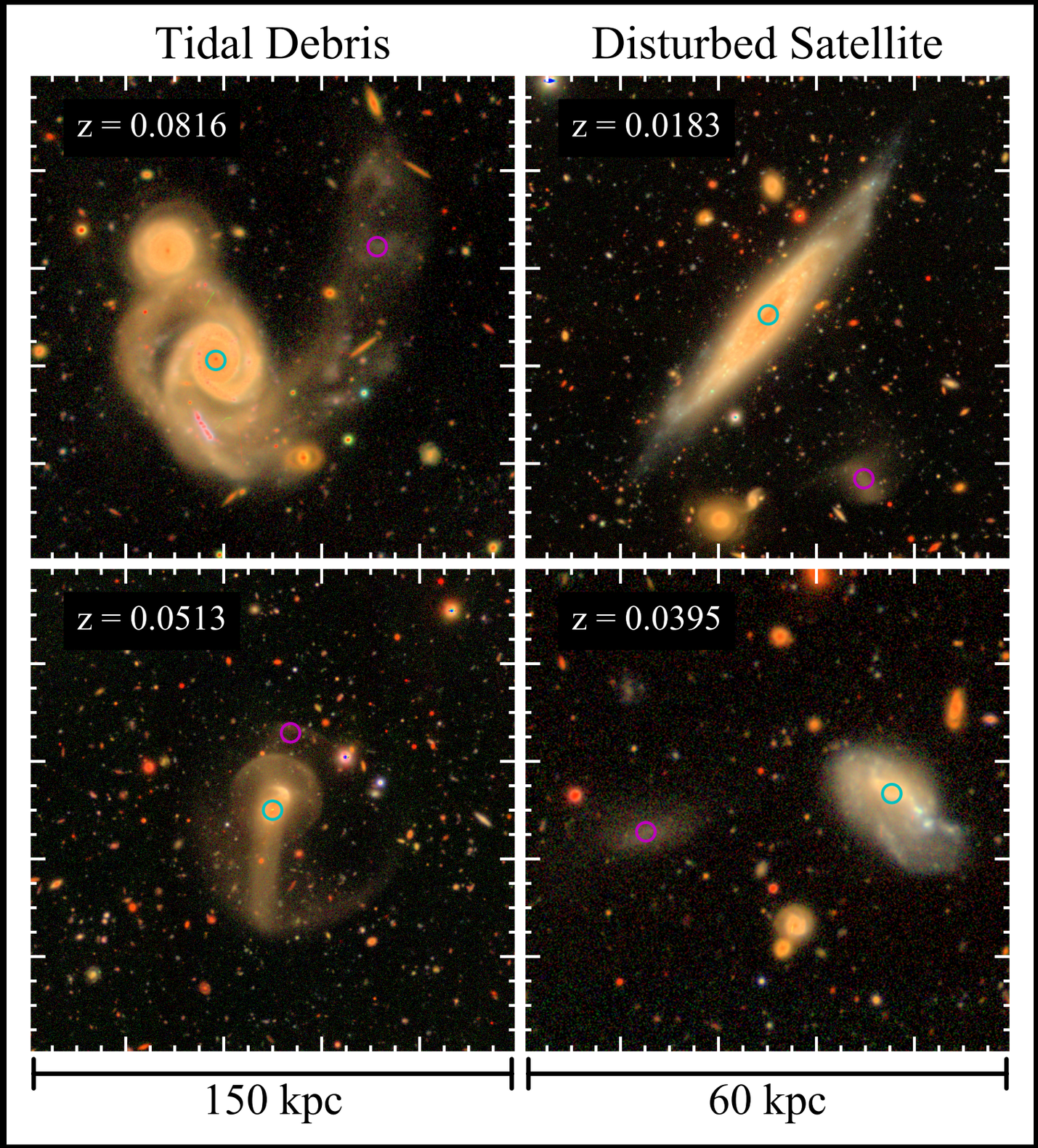
Greco et al. 2017, ApJ submitted

LSB False Positives: Galactic Cirrus



Greco et al. 2017, ApJ submitted

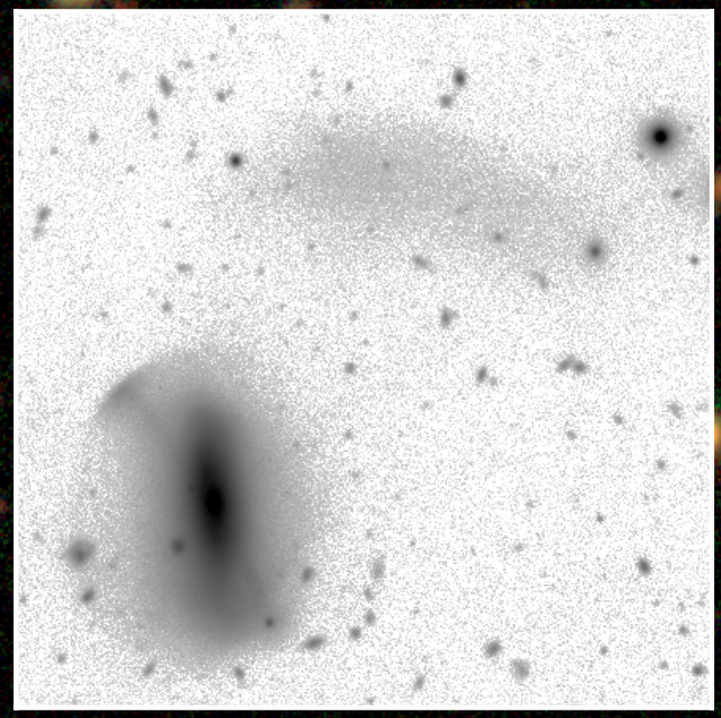
LSB False Positives: Tidal Debris?



Greco et al. 2017, ApJ submitted

LSB False Positives: Tidal Debris?

$$\frac{\sim 50 \text{ kpc at } z = 0.043}{1'}$$



Greco et al. 2017, PASJ accepted

LSBG Sample

Blue LSBGs

Red LSBGs

55″

LSBG-305 LSBG-750 LSBG-497 LSBG-435 LSBG-505 LSBG-709

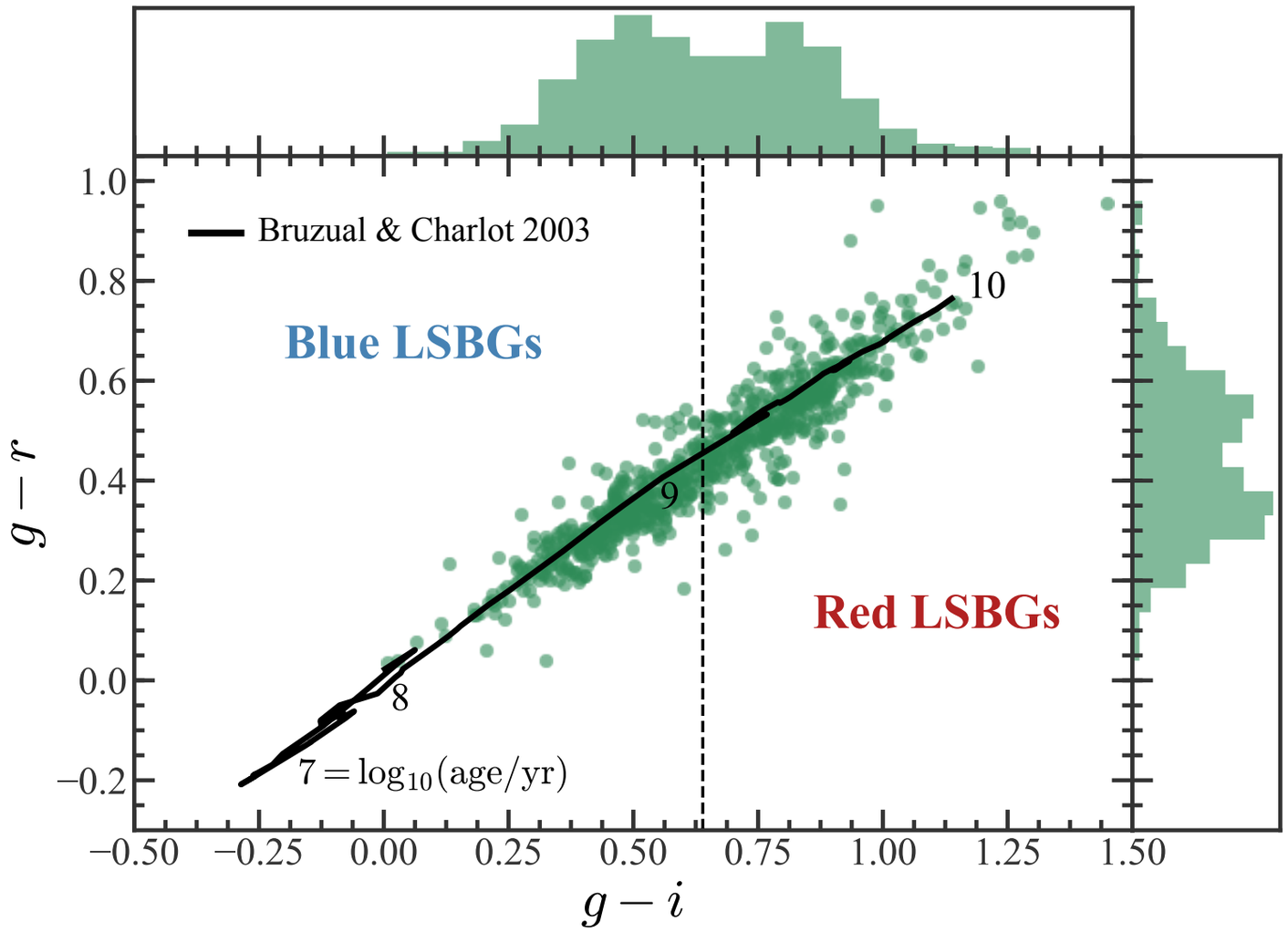
LSBG-157 LSBG-274 LSBG-540 LSBG-17 LSBG-507 LSBG-711

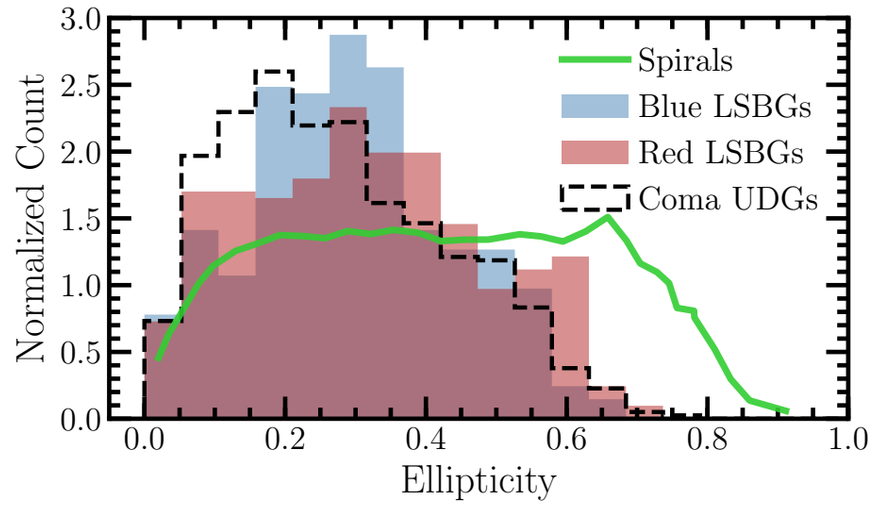
LSBG-621 LSBG-605 LSBG-603 LSBG-490 LSBG-506 LSBG-238

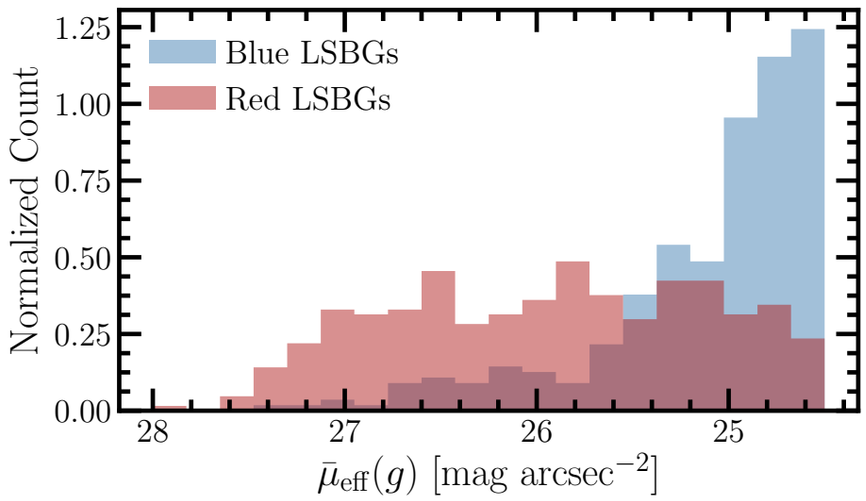
LSBG-522 LSBG-407 LSBG-333 LSBG-159 LSBG-431 LSBG-622

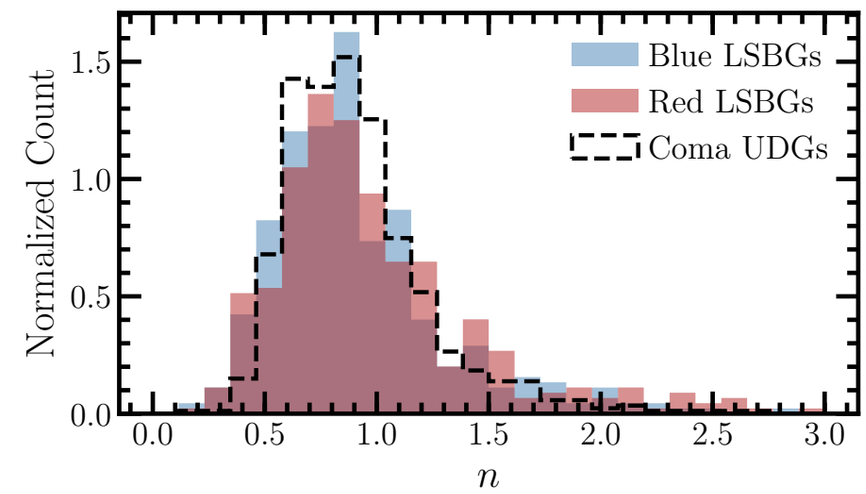
LSBG-227 LSBG-746 LSBG-689 LSBG-114 LSBG-524 LSBG-632

LSBG Sample: Parameter Distributions

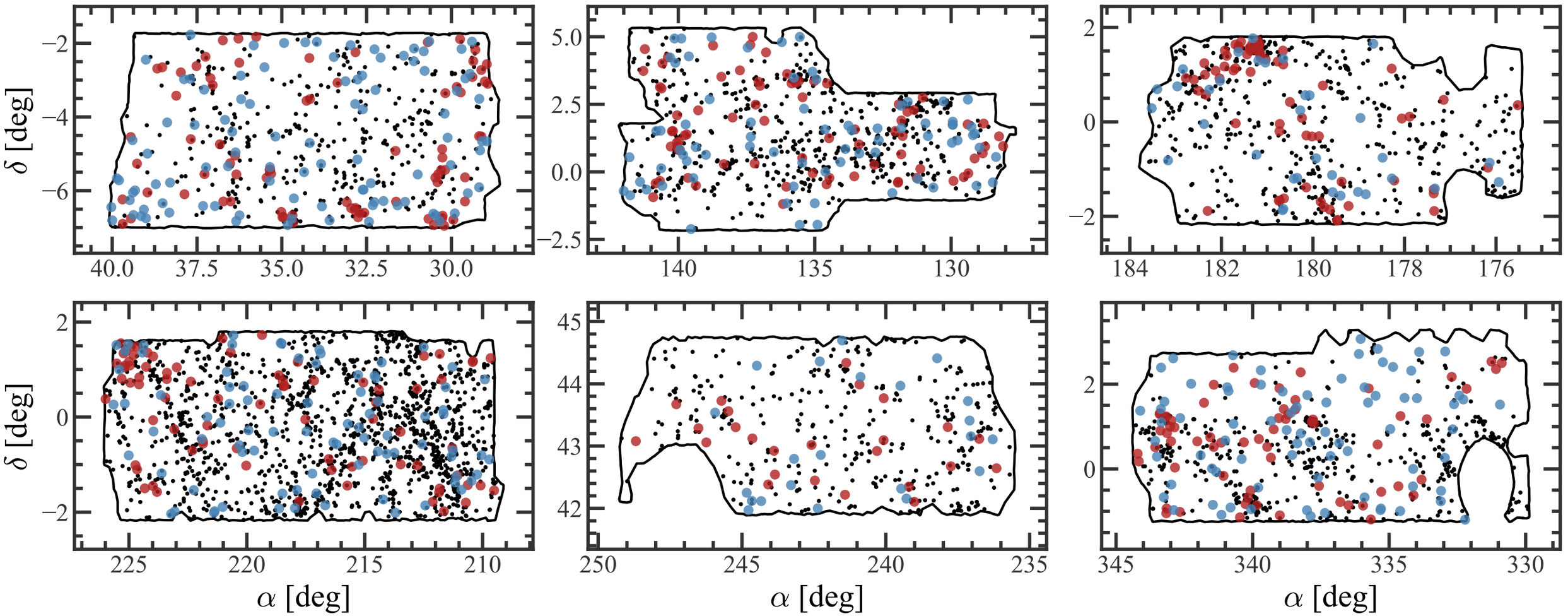






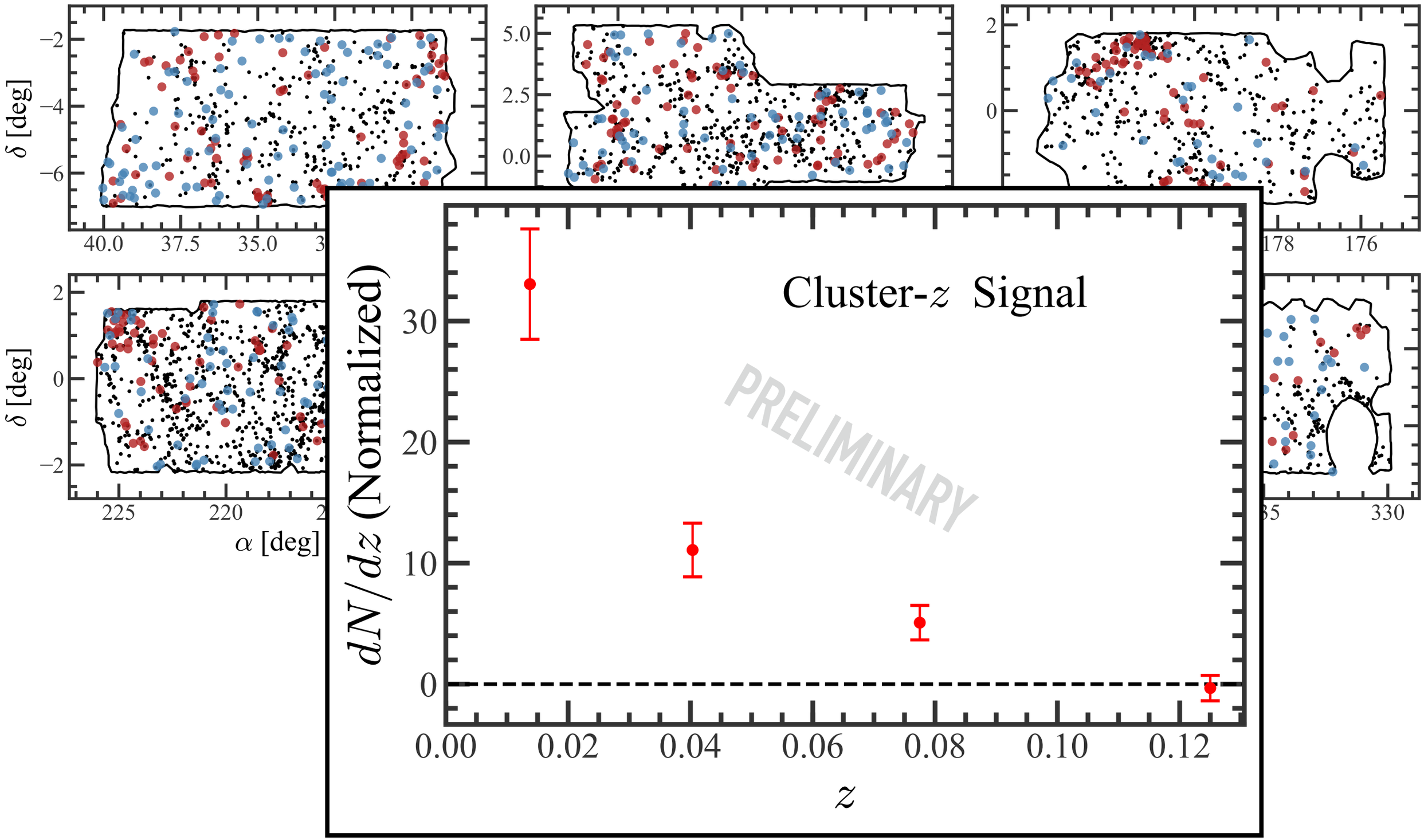


LSBG Sample: Spatial Distribution



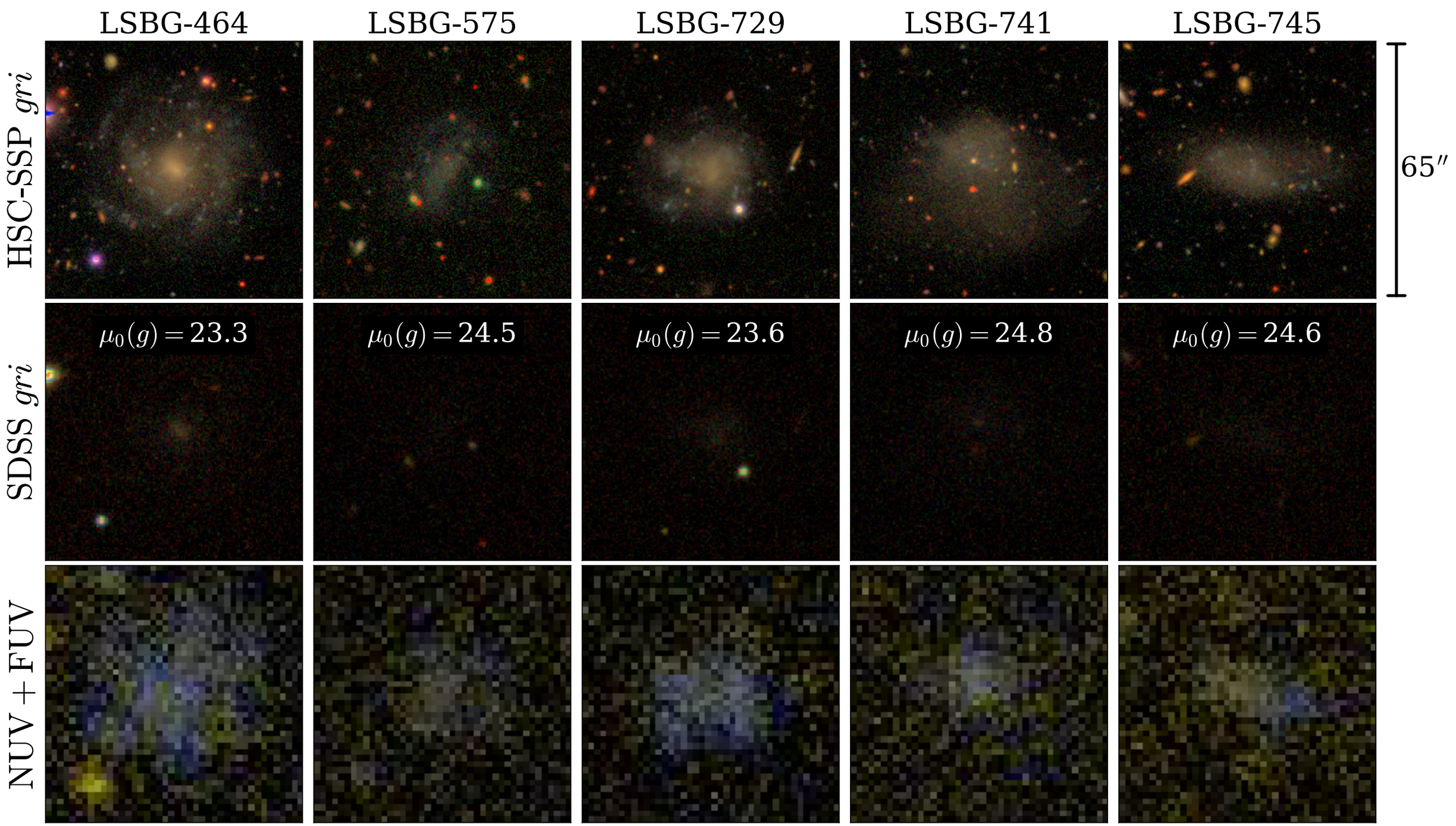
Greco et al. 2017, ApJ submitted

LSBG Sample: Spatial Distribution



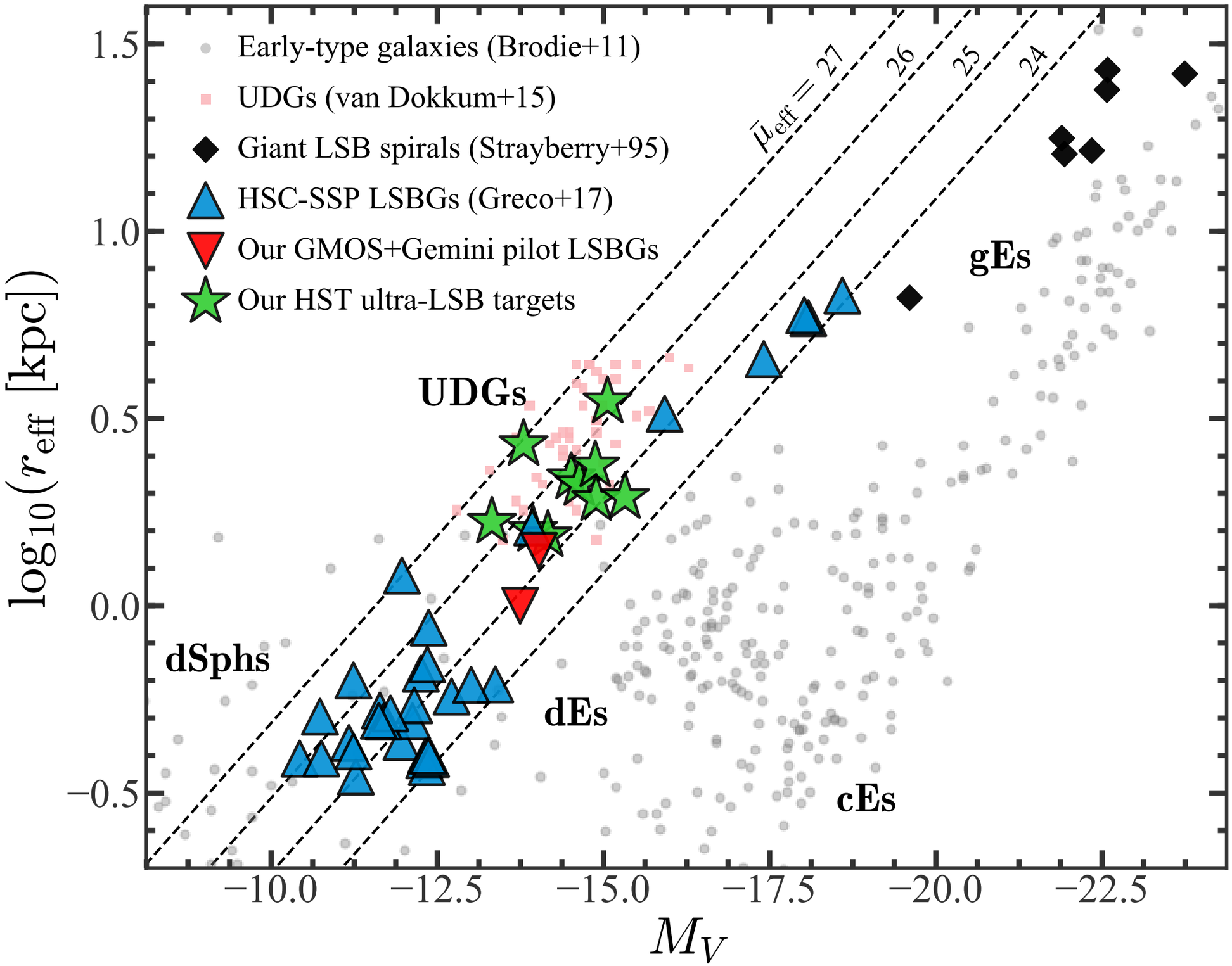
Greco et al. 2017, ApJ submitted

LSBG Sample: Catalog Crossmatching



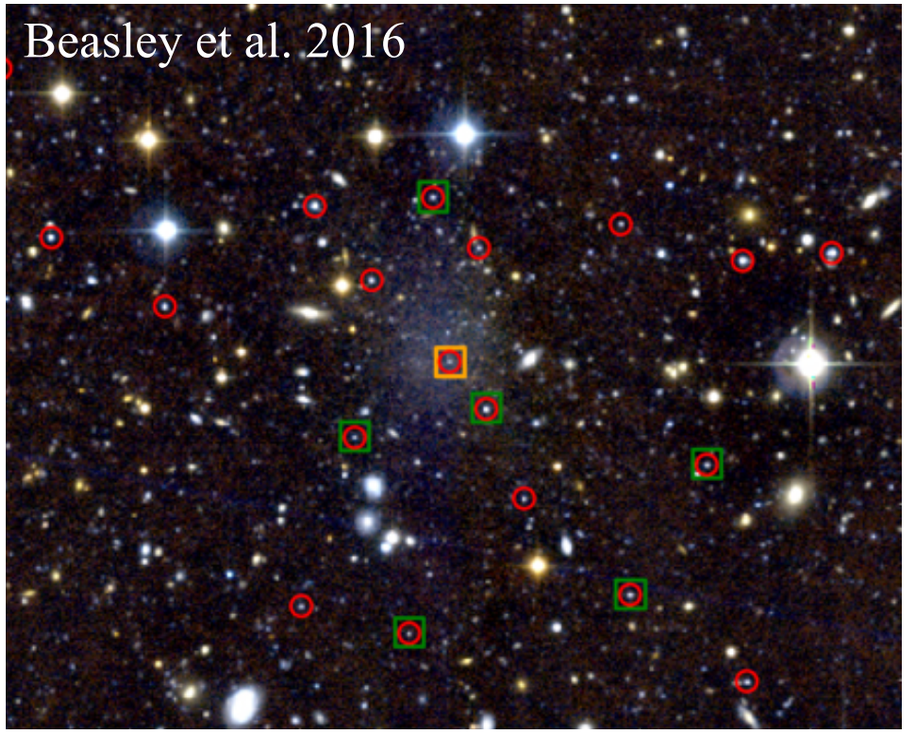
Greco et al. 2017, ApJ submitted

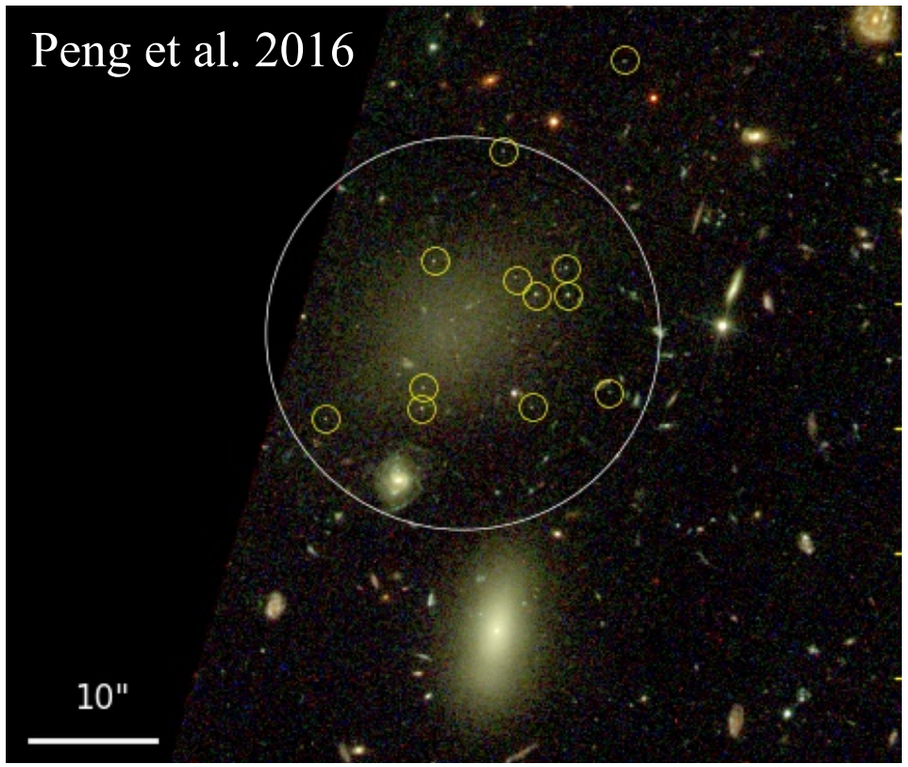
Size-Luminosity Relation



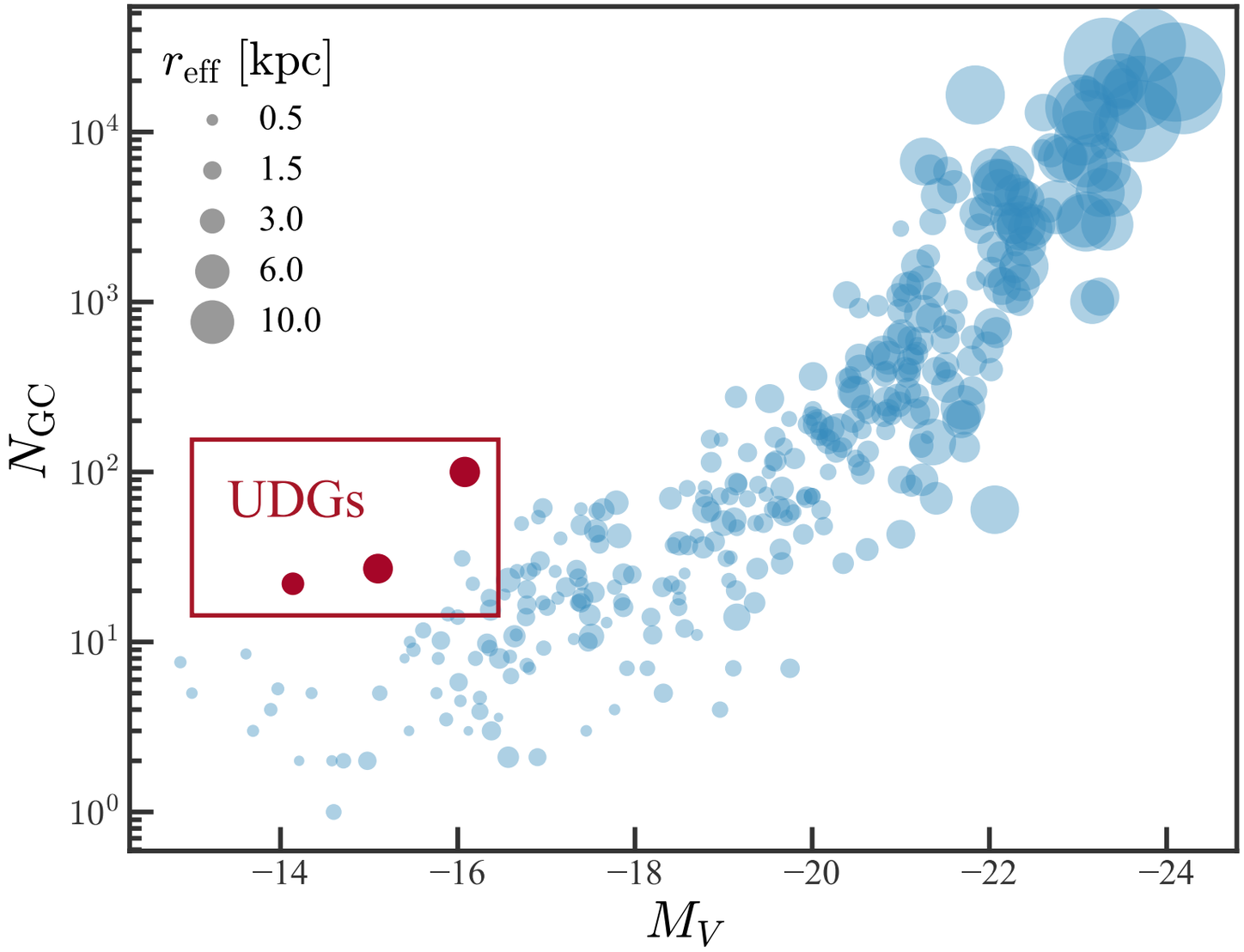
What's Next?

What's Next?





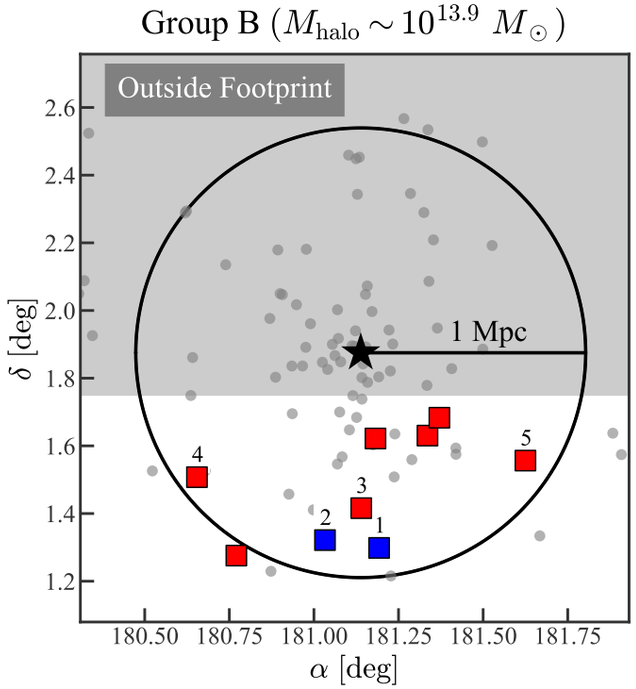
UDGs & rich globular cluster systems

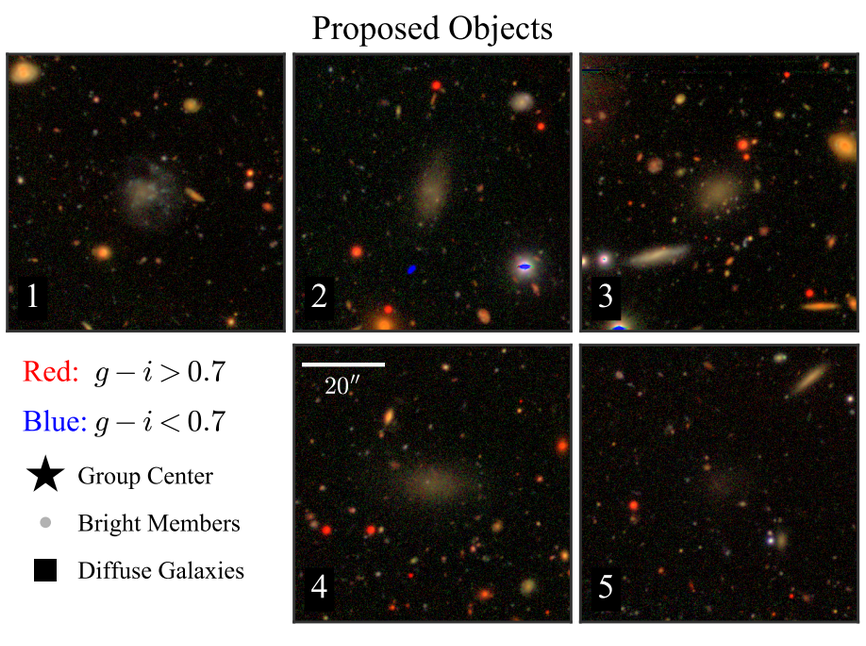


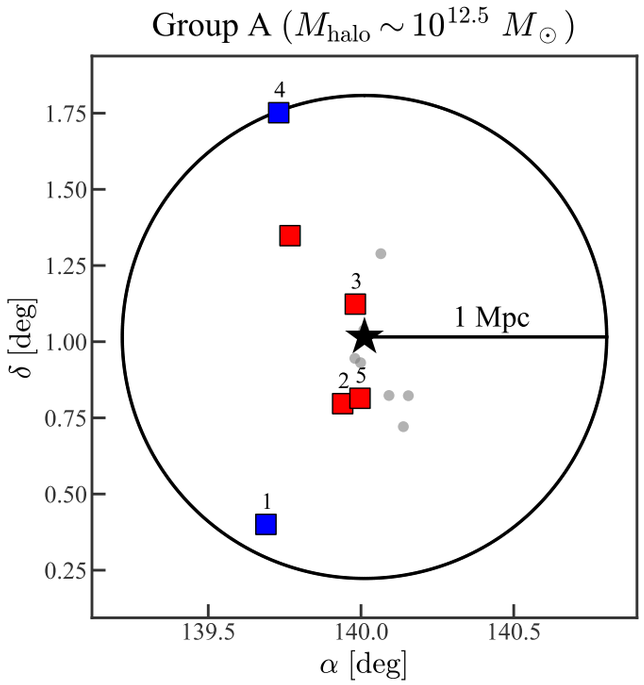
Data from Harris et al. 2013

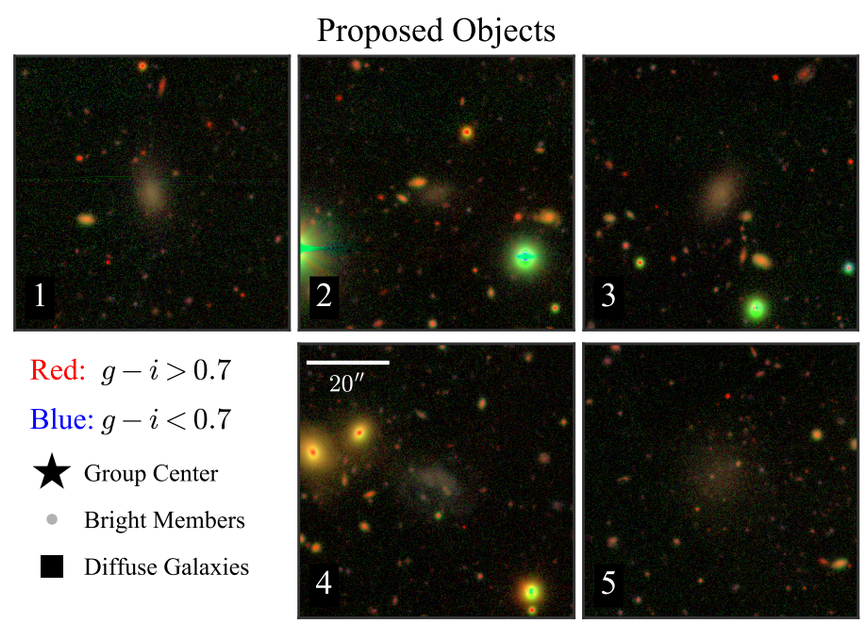
What's Next?

Counting globular clusters with HST



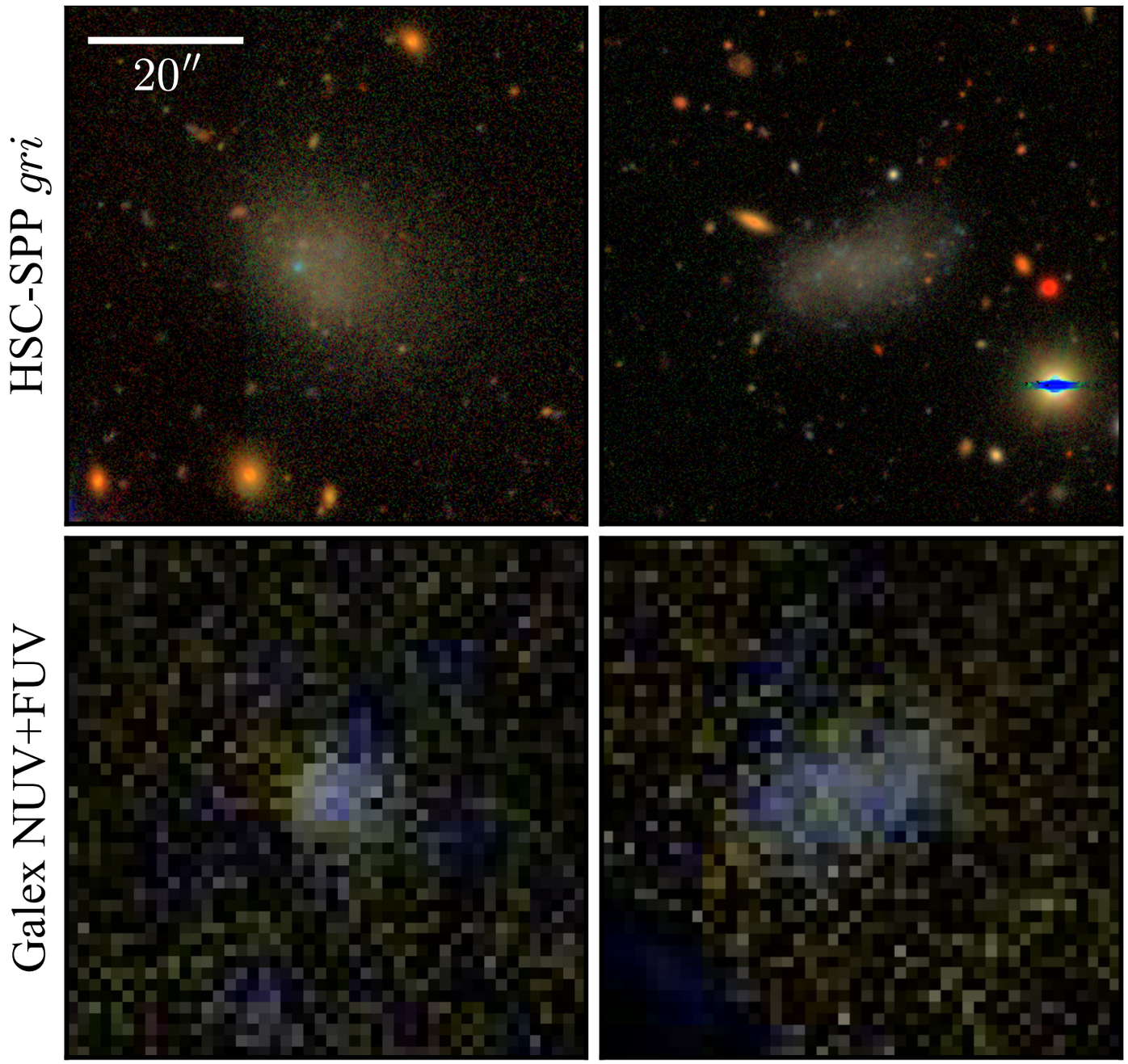






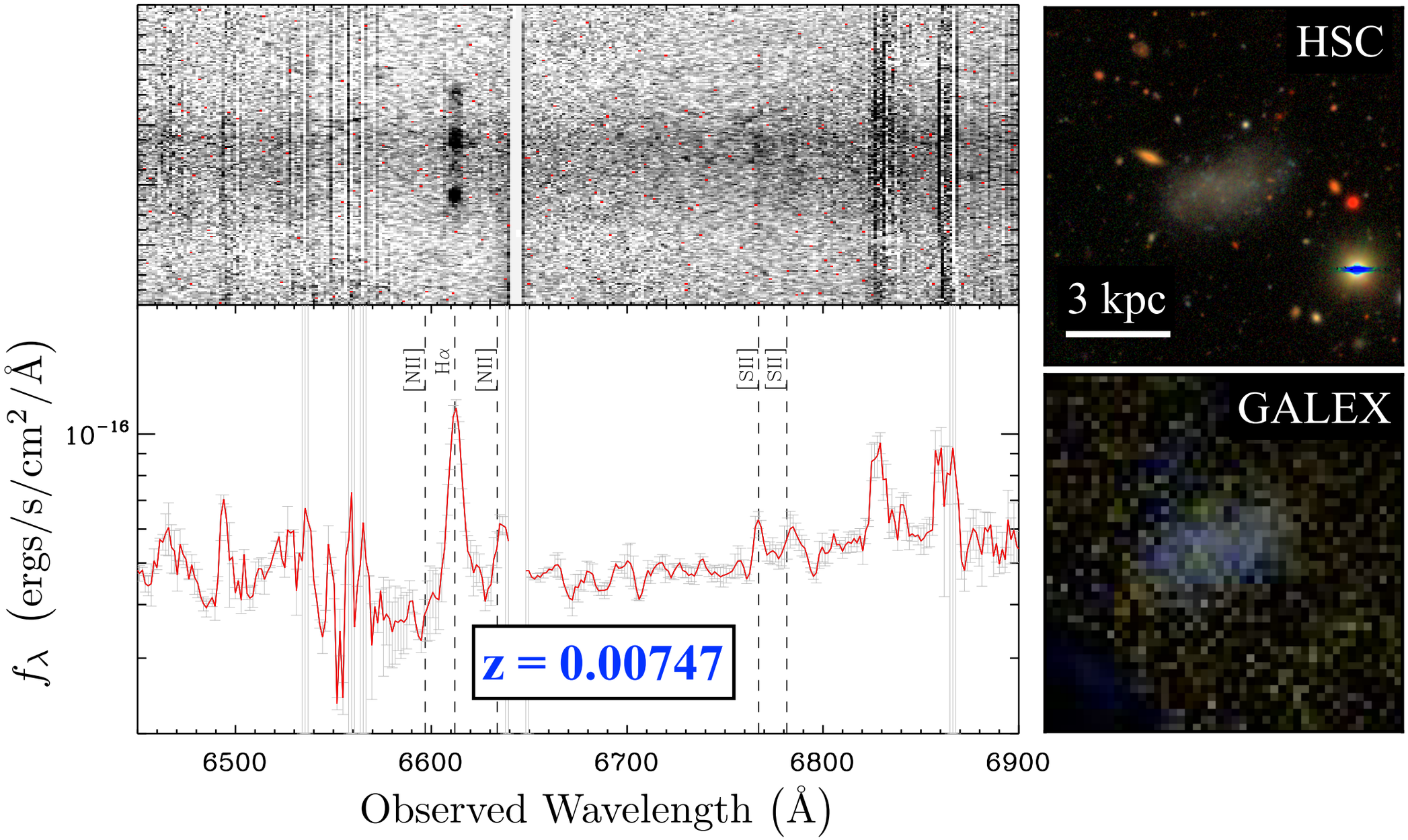
What's **Next**?

Redshifts with GMOS on Gemini



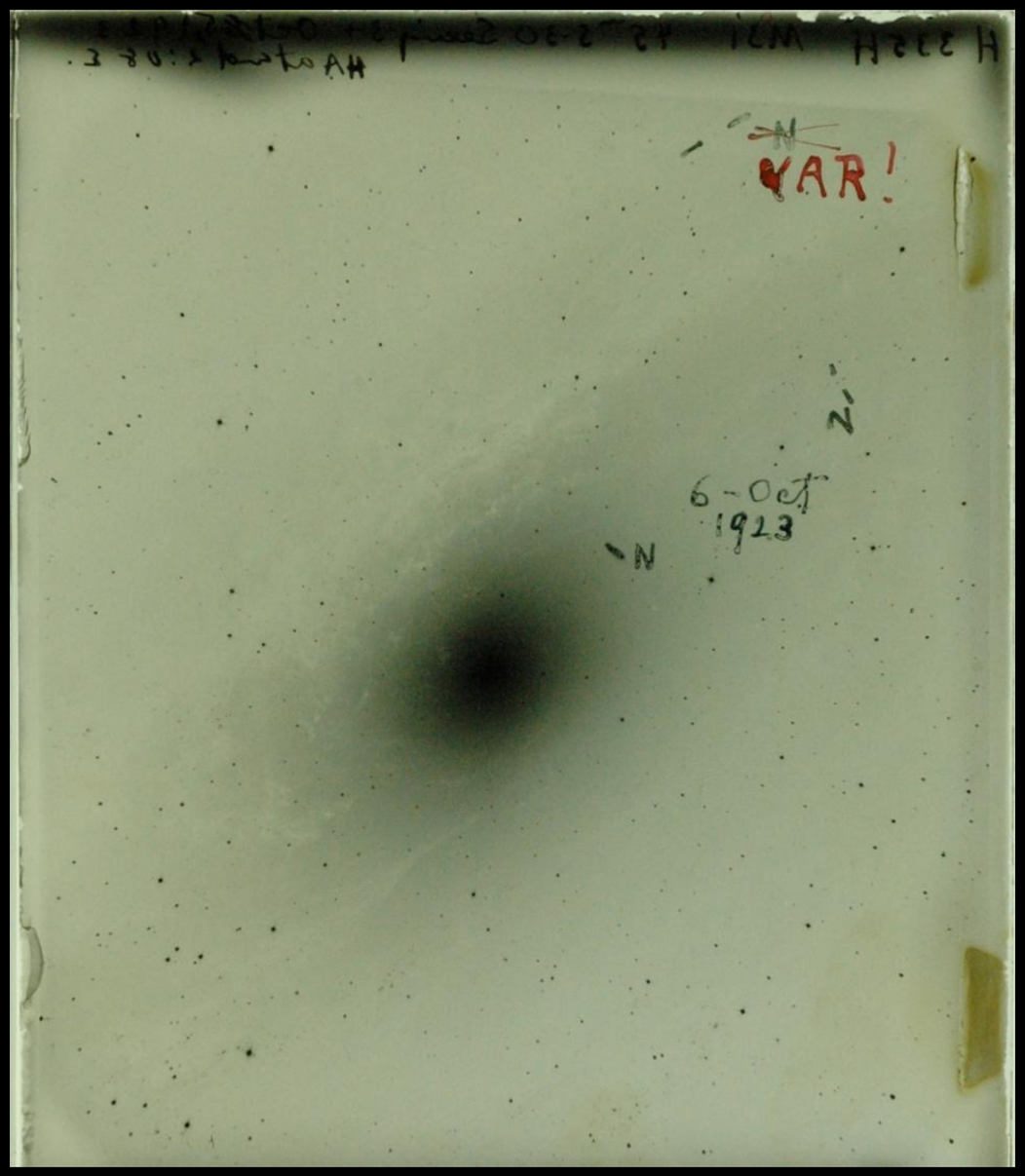
What's **Next**?

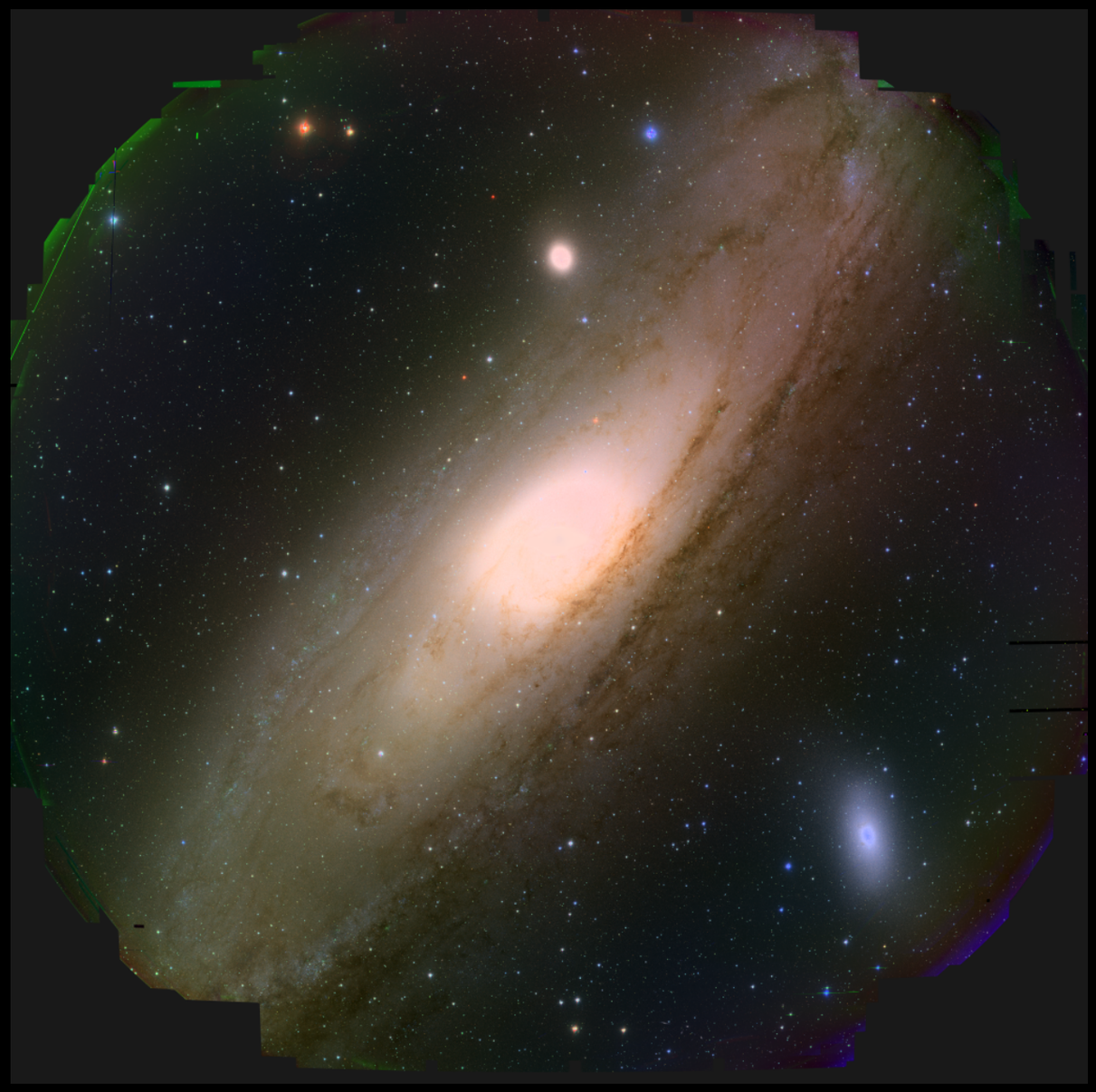
Redshifts with GMOS on Gemini



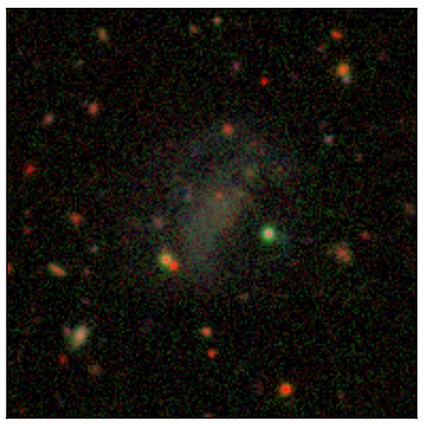
Greco et al. 2017, in prep.

Progress

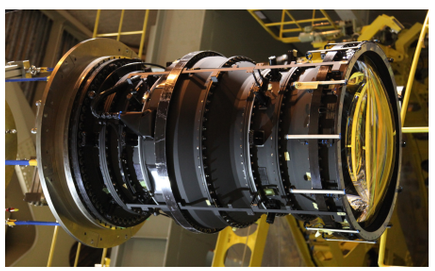




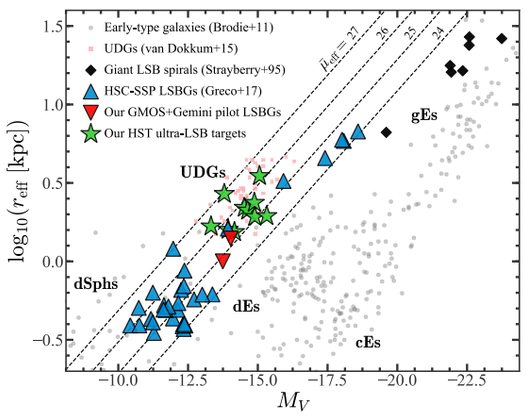
Summary



Low-surface-brightness galaxies (LSBGs) are a significant yet poorly understood component of the galaxy population



Exquisite imaging afforded by HSC promises to provide an unprecedented view of LSBGs over 1400 deg^2



We have a diverse sample of ~800 LSBGs, which we are actively following up from the ground and space

Special thanks to my collaborators!

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