CLuster EVOlution Research
CLEVOR

CLEVOR's activities to explore the low surface brightness(LSB) Universe

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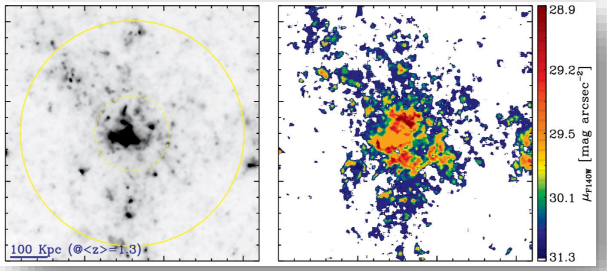
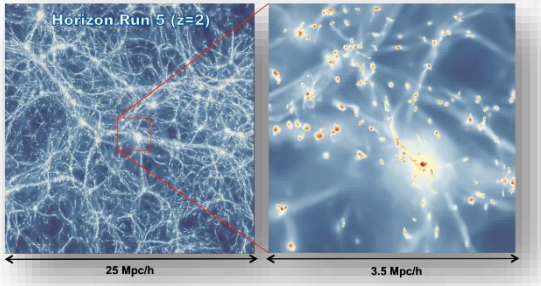
Outline

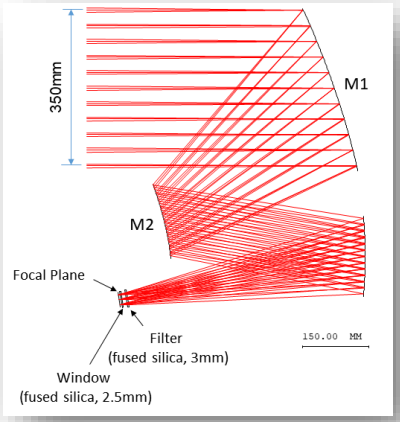
- Why exploring the LSB Universe?
- Activities for the LSB Universe exploration
  - Observations:
    - ICL(high-z, mid-z, low-z)
    - dwarfs around giant galaxies



  - Simulations:
    - ICL origin



  - Developing Telescope
    optimized to explore the LSB Universe



CLEVOR (CLuster EVOlution Research)

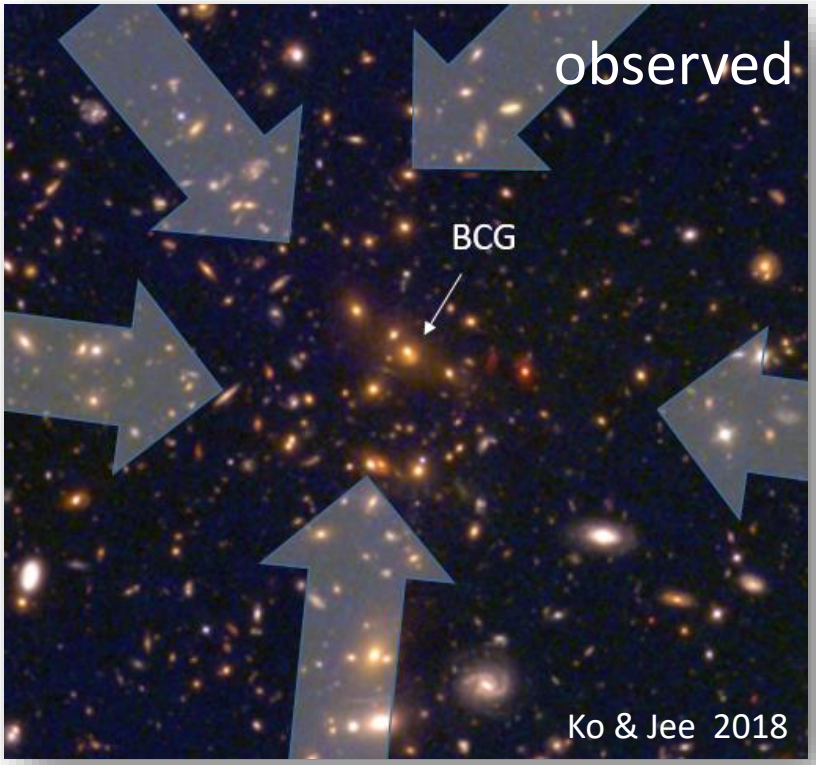
Q1: How BCGs are formed?
(*BCG assembly history*)

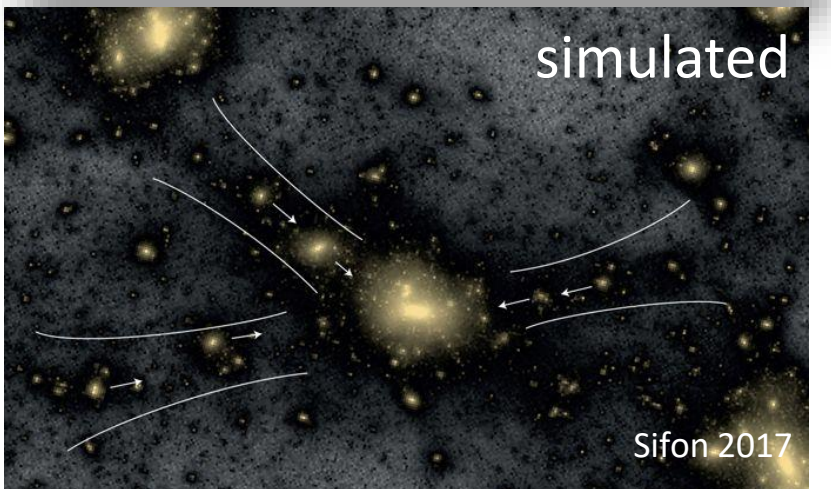
Q2: When and how intracluster stars are formed? (*origin of the ICL*)

Q3: Cluster mergers …quench, trigger, or little effect on SF and AGN activities in cluster galaxies?
(*origin of the red-sequence & environmental effect on the galaxy evolution*)

Q4: Large-scale structure … effect on the cluster evolution?
(*origin of the fossil clusters & environmental effect on the cluster evolution*)

Q5: How to classify the dynamical state of galaxy clusters?
(*cluster merging/evolution history*)

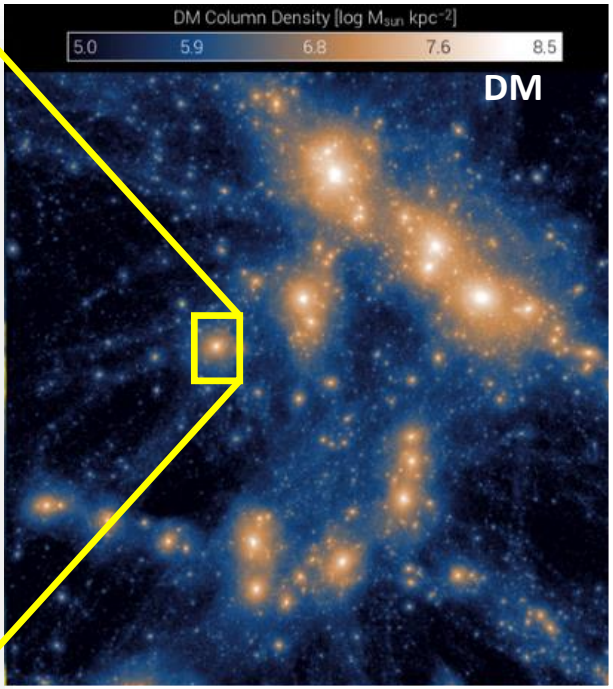




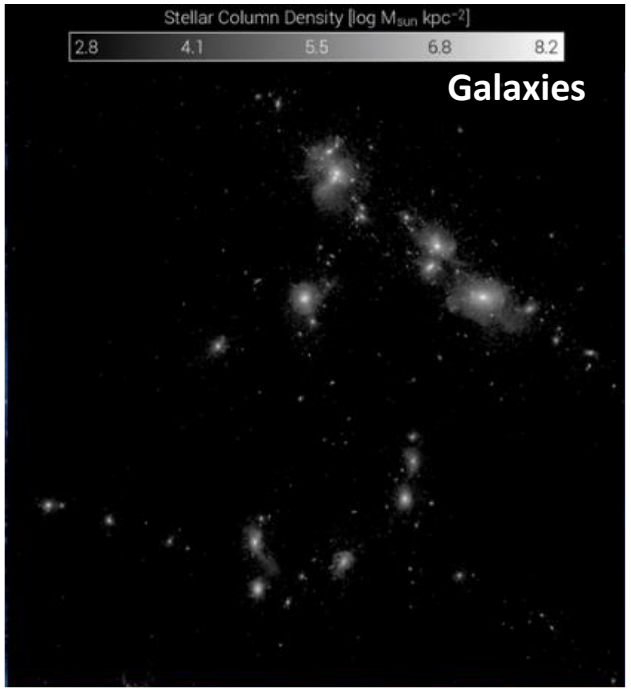
Why LSB? … DM tracer?

LSB observation (NGC 474)

DM simulation



Galaxy simulation



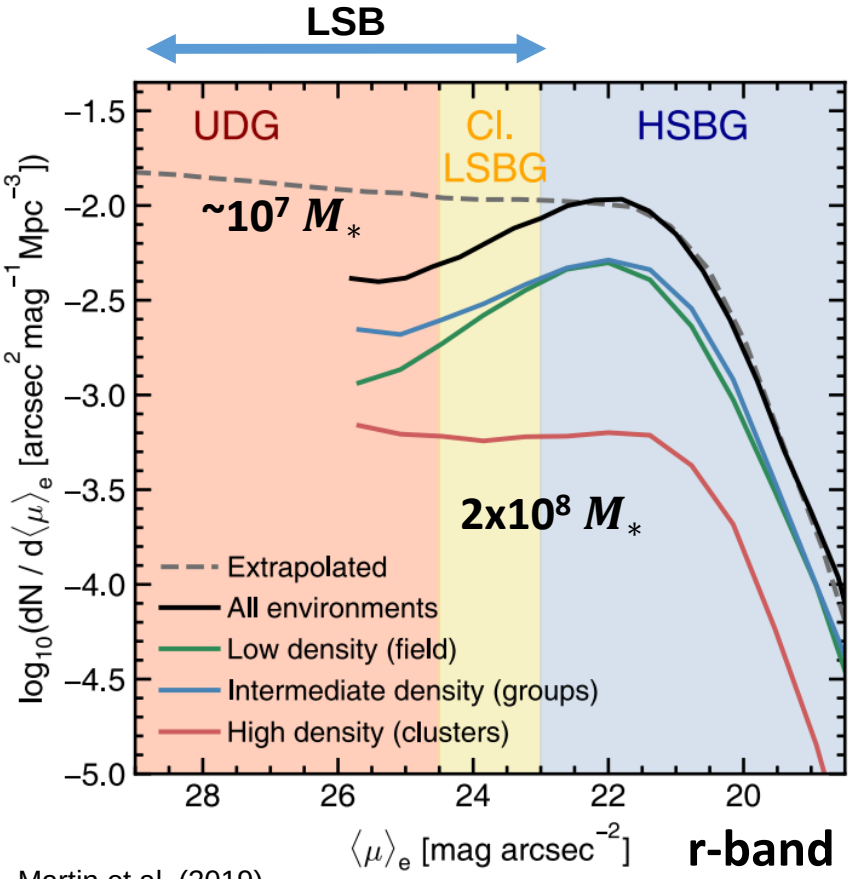
Credit: TNG Simulations

LSB signatures around galaxies → hierarchical structure formation

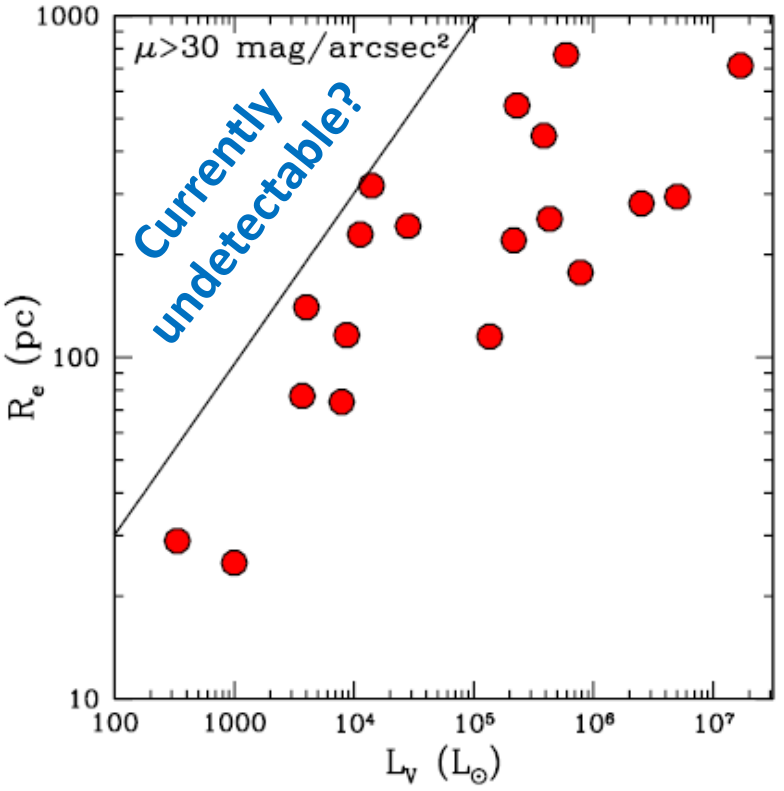
LSB filament → DM structures

why LSB? … LCDM

- **SB limits of surveys**
  - ✓ SDSS rapidly incomplete at ~24
    (Stripe 82: 25.5) mag arcsec^{-2}
- **missing satellite problem?**
  - ✓ Galaxy formation model …
  - ✓ Detection limit?



Martin et al. (2019)

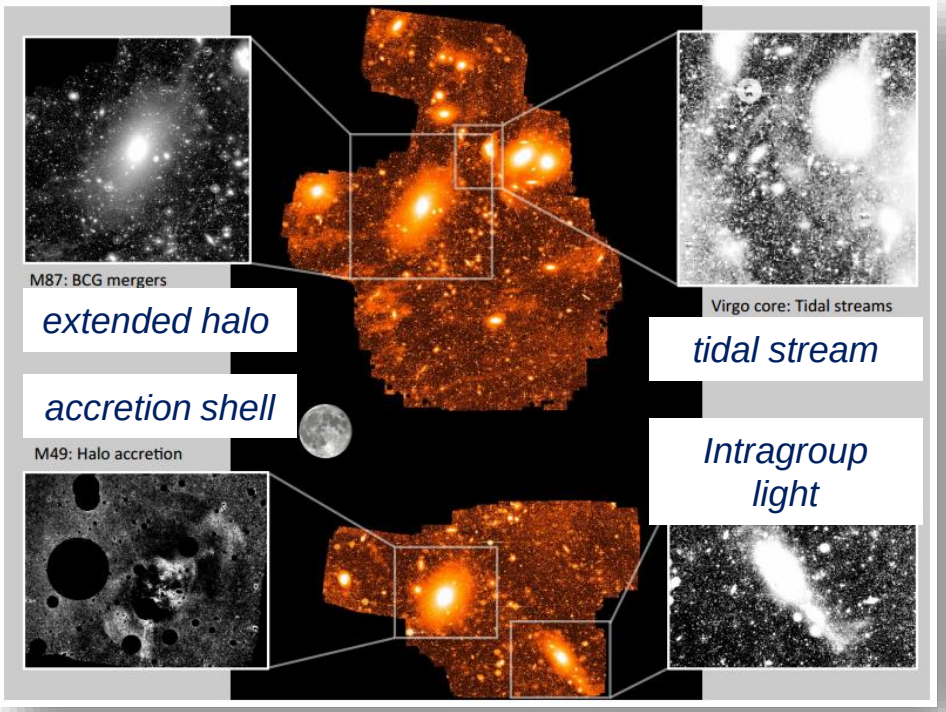


Bullock (2010)

why LSB? … Formation history

Virgo cluster

>28 mag arcsec^{-1}



LSB … → reflects the history of the interactions

why LSB? ... UDG

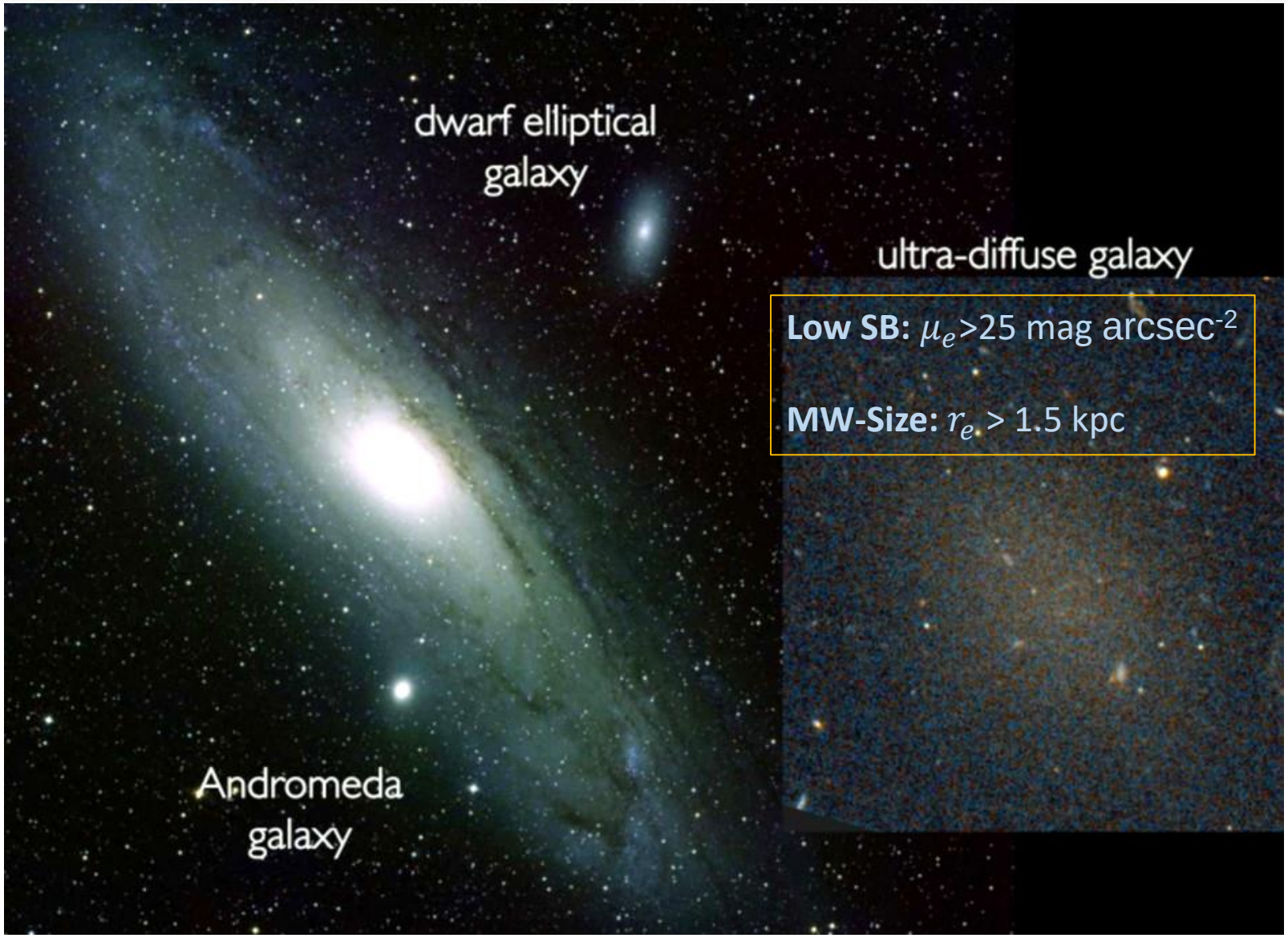
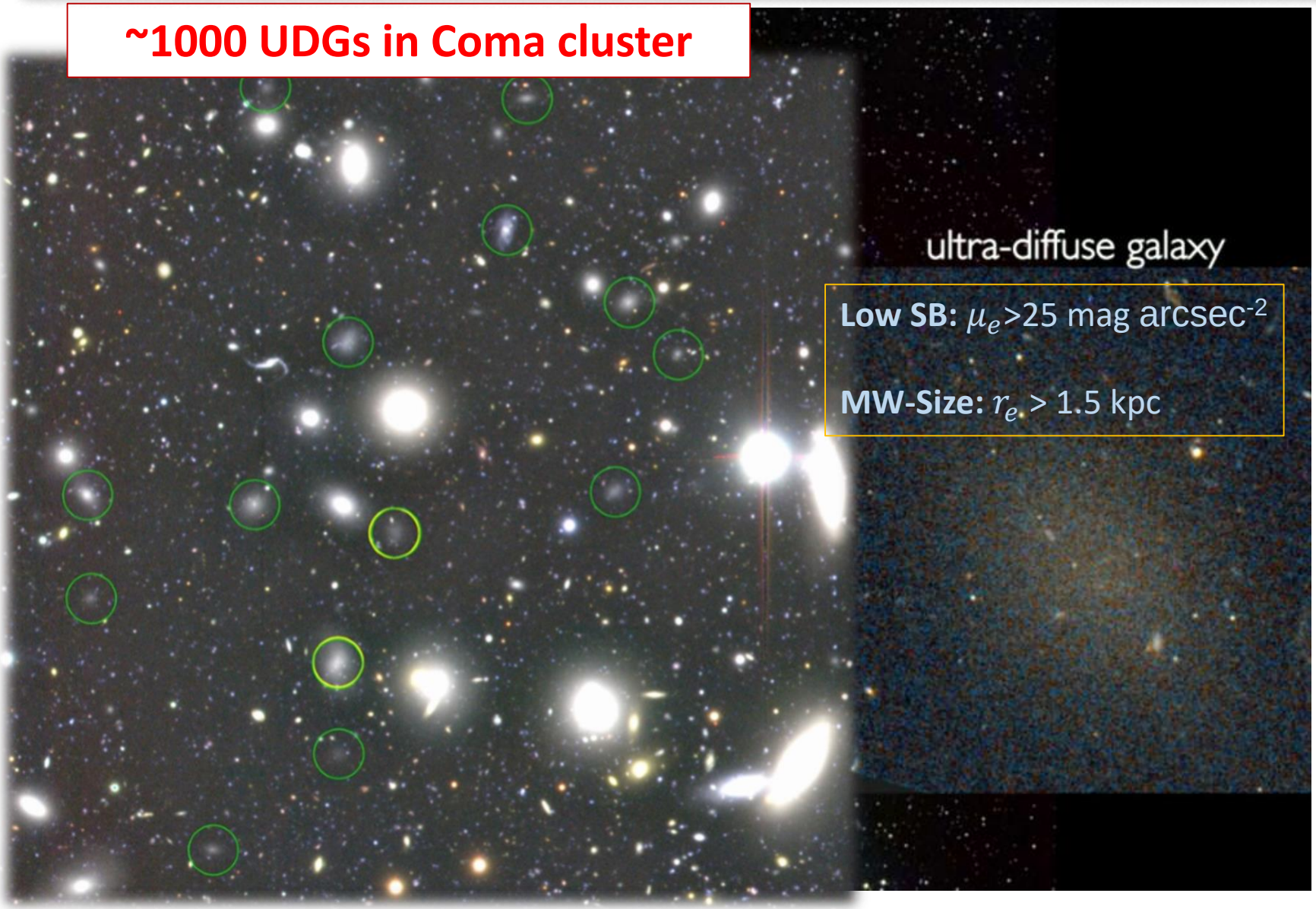


Image credit: Schoening/Harvey/van Dokkum/NASA/ESA Hubble Space Telescope

why LSB? ... UDG

~1000 UDGs in Coma cluster

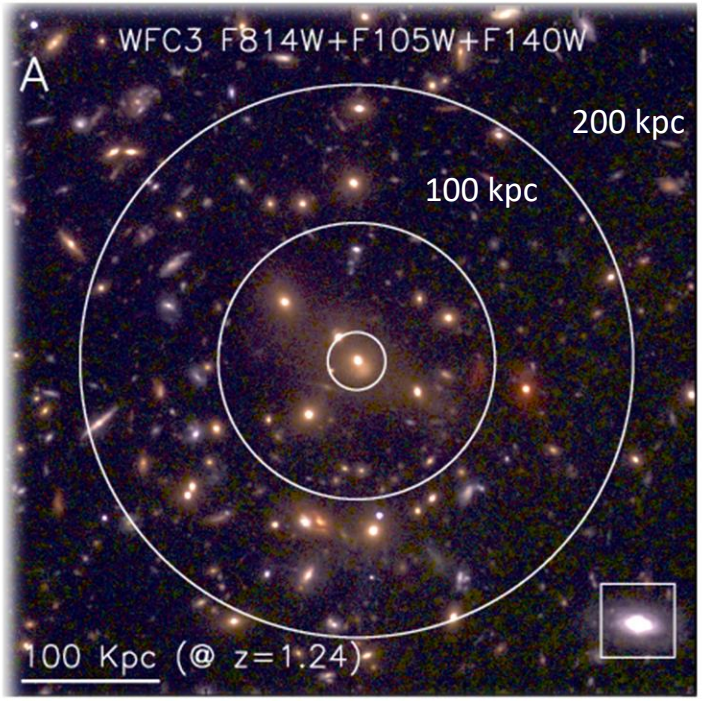


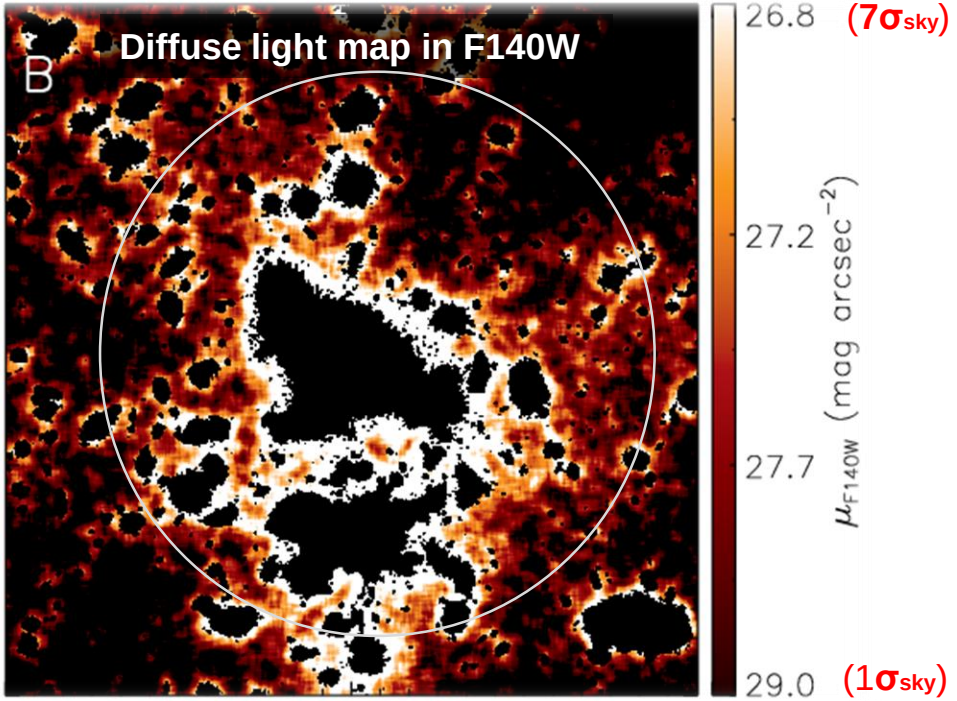
Koda et al. 2015

why LSB? … ICL

Ko & Jee (2018)

Intracluster light (ICL) 분포

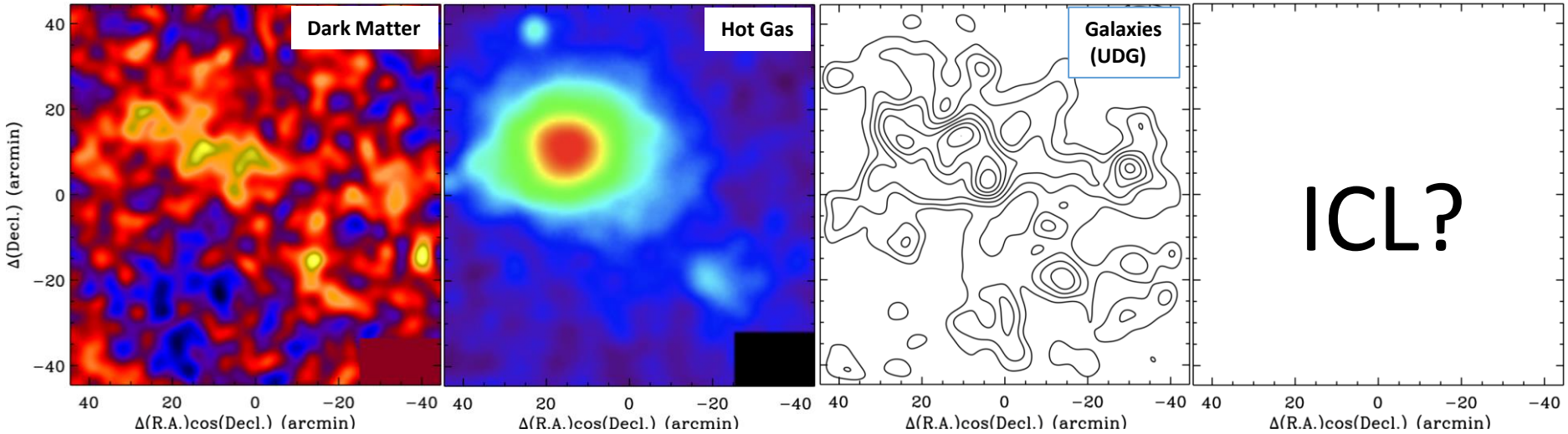




- ICL extended to ~200 kpc from the BCG
- This is the most distant galaxy cluster to date
- Contrary to previous studies, the **ICL is already exists significantly z>1**

Observations: w/ HST, Gemini, Subaru, KMTNet

low-z: Coma(z=0.02), w/ Subaru SC & HSC *[Yoo, Ko, Hwang et al. 2021, to be submitted]*



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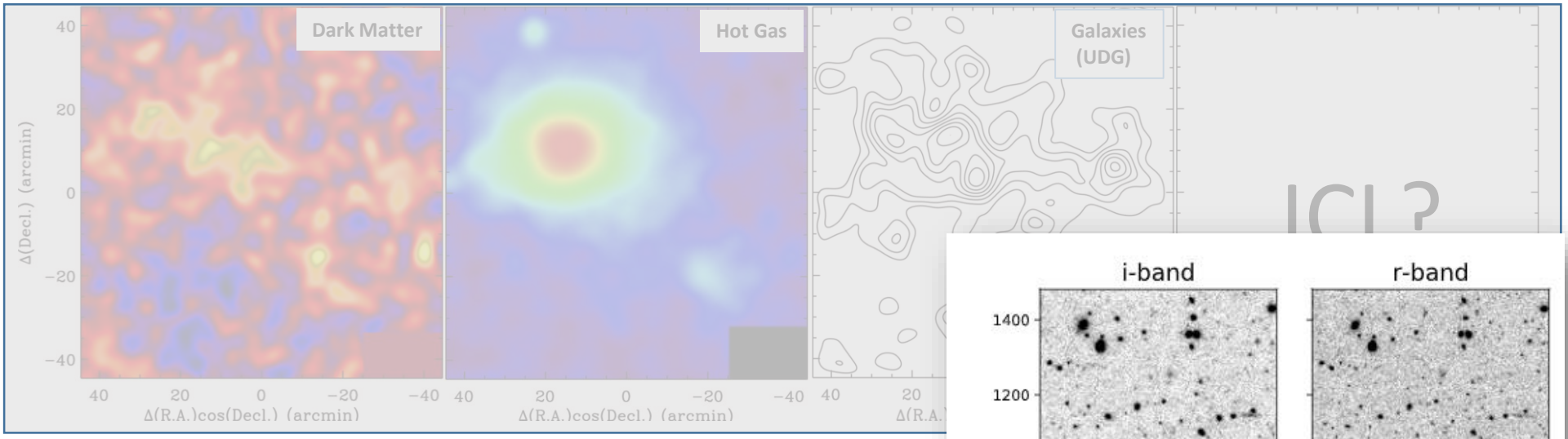


mid-z: RX J1054(z=0.47), w/ Gemini GMOS

[Yoo, Ko, Yang, Lee et al. 2020, to be submitted]

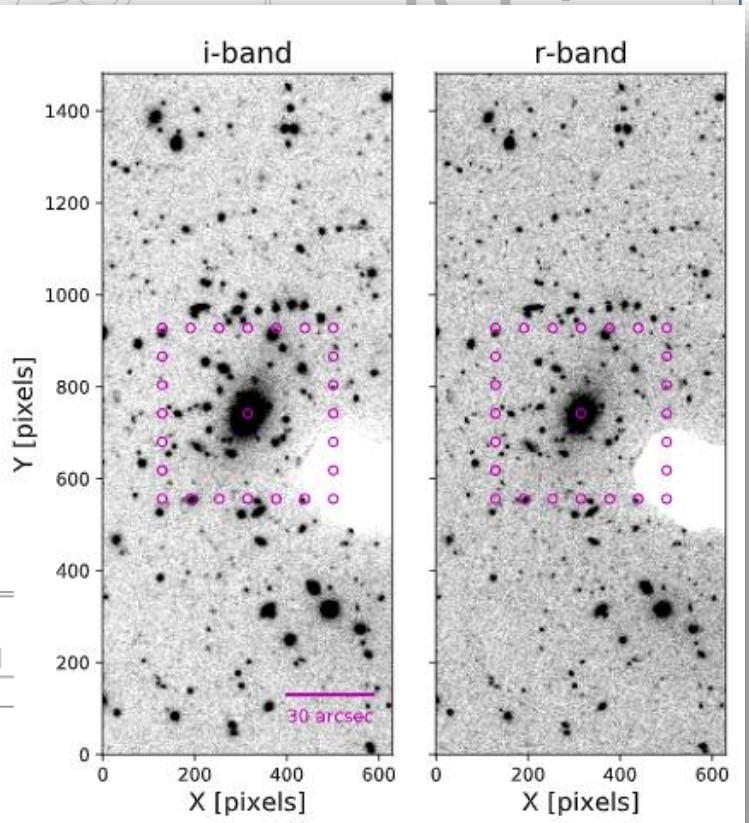


Table 1. Target description

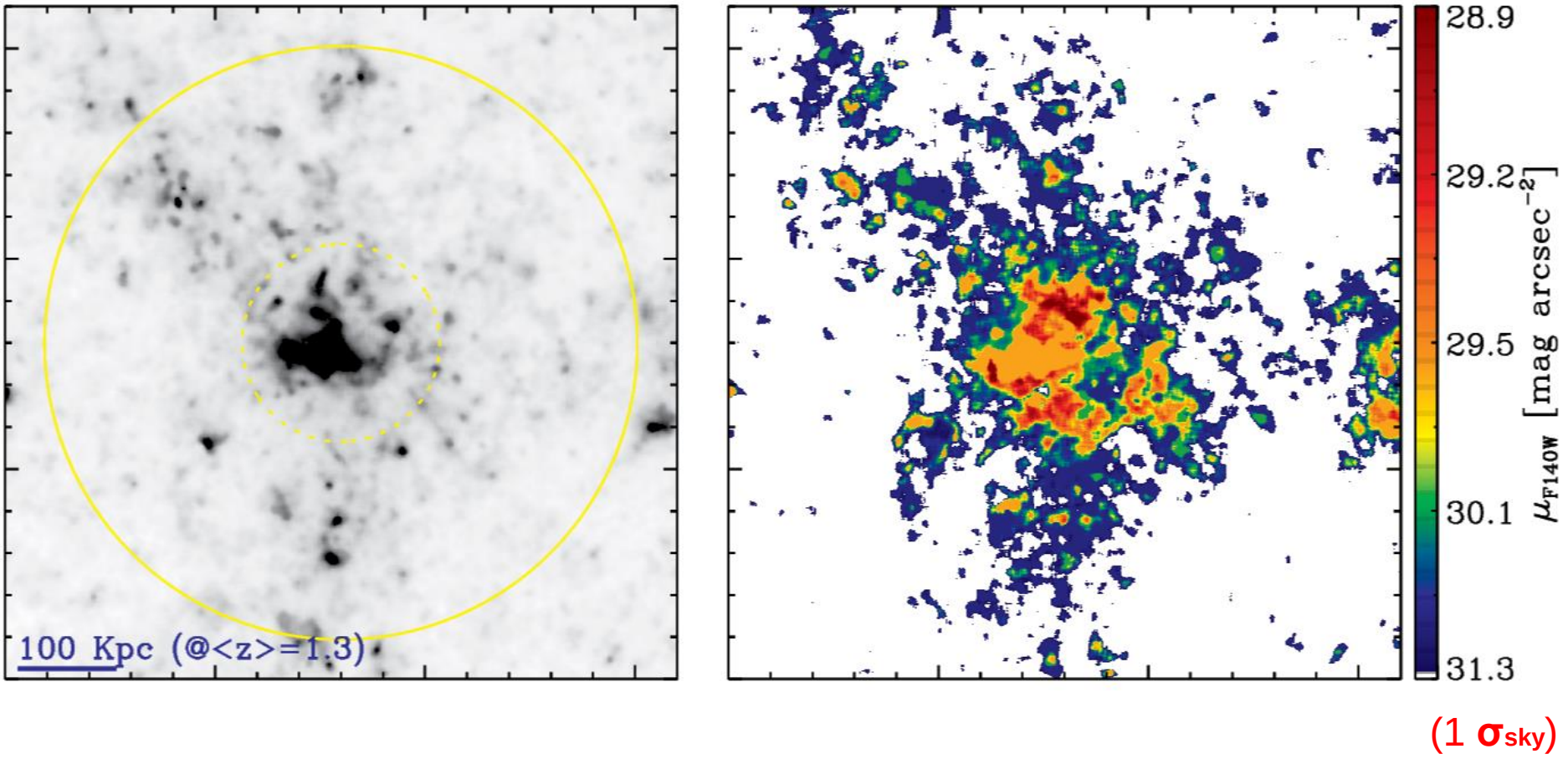
SDSS name	ROSAT name	R.A (ha)	Dec (deg)	z	L_X $[10^{44} erg/s]$	R_G[a] [Mpc]	M_{vir}[a] $[10^{15} M_\odot]$	r_{vir}[a] [Mpc]
J105452.03+552112.5	RX J105453.3+552102	10 : 54 : 52.03	+55:21:12.5	0.47	2.39	0.92	0.89	1.45

[a]The projected gravitational radius, the virial mass and the virial radius are calculated in section 5.1.

Observations: w/ HST, Gemini, Subaru, KMTNet

high-z: See Change clusters(z>1), w/ HST WFC3 *[Ko, Jee et al. 2020, to be submitted]*

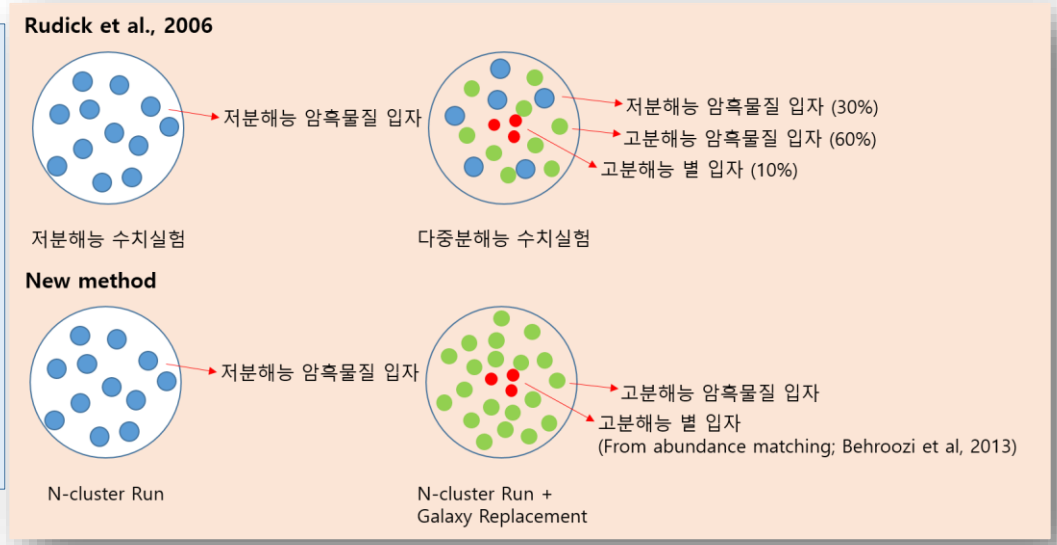
6 clusters(<z>=1.3) stacked

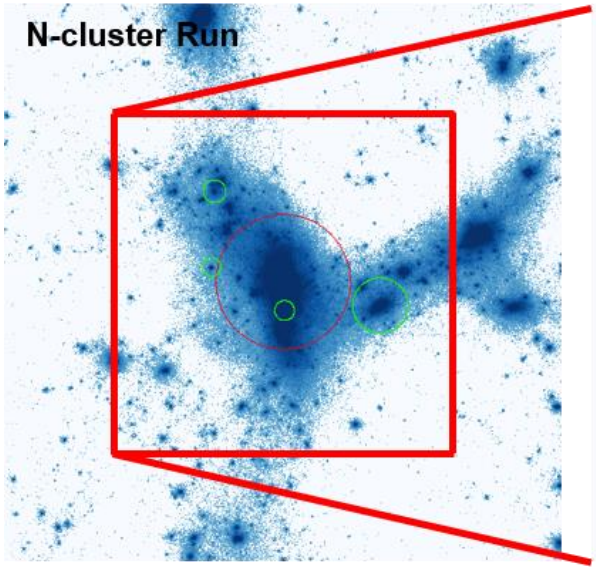


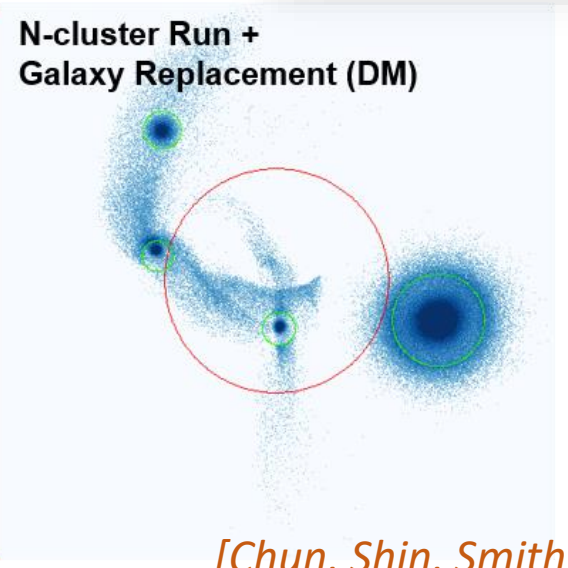
Simulations: w/ N-cluster, HR5, IllustrisTNG

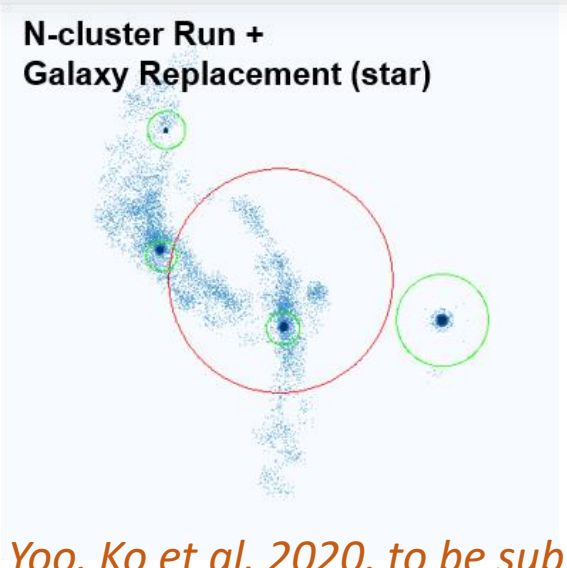
N-cluster Run + galaxy replacement:

- ~3000 galaxy clusters
- In a wide range of cluster **masses, merging history(dynamical state), age**





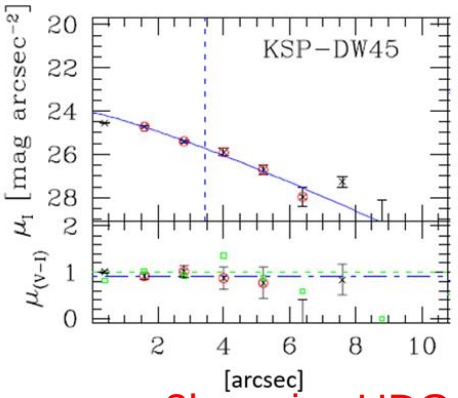


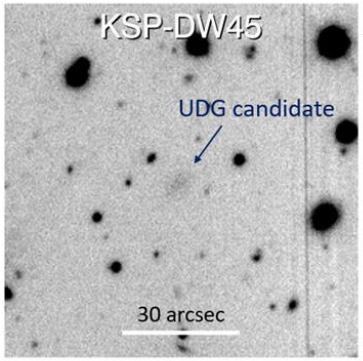


[Chun, Shin, Smith, Yoo, Ko et al. 2020, to be submitted]

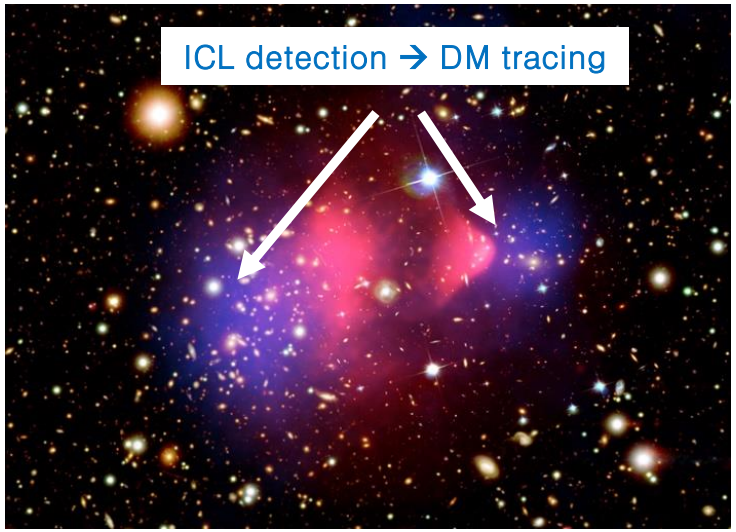
LSB telescope project: w/ small D & wide FoV

3. [2026~] ICL/UDG detection



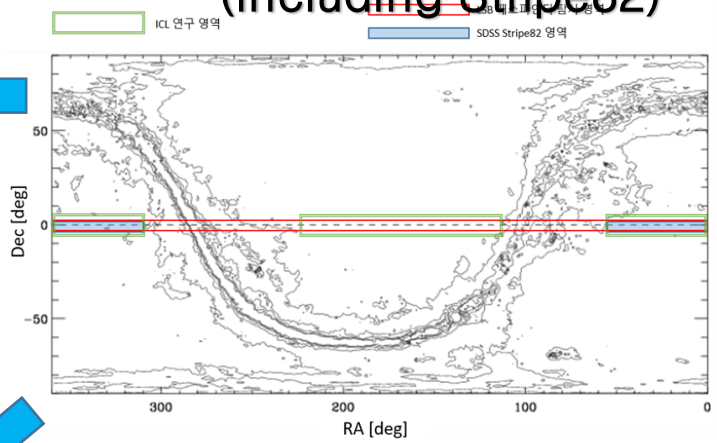


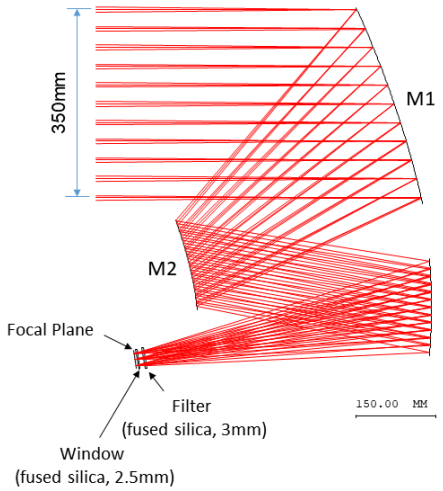
~3kpc-size UDGs within ~20 Mpc



>3000 clusters @ z<0.1

2. [2024−26] LSB survey (including Stripe82)

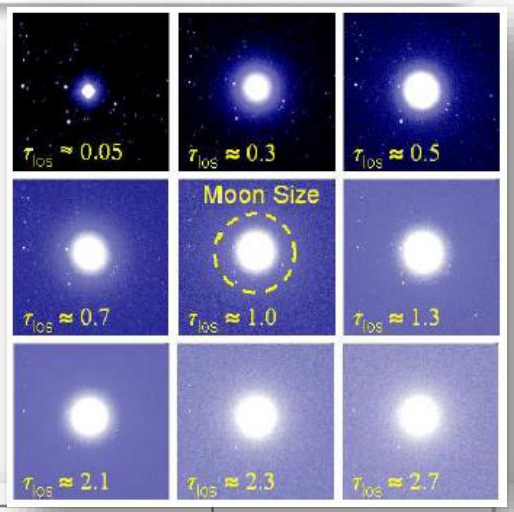


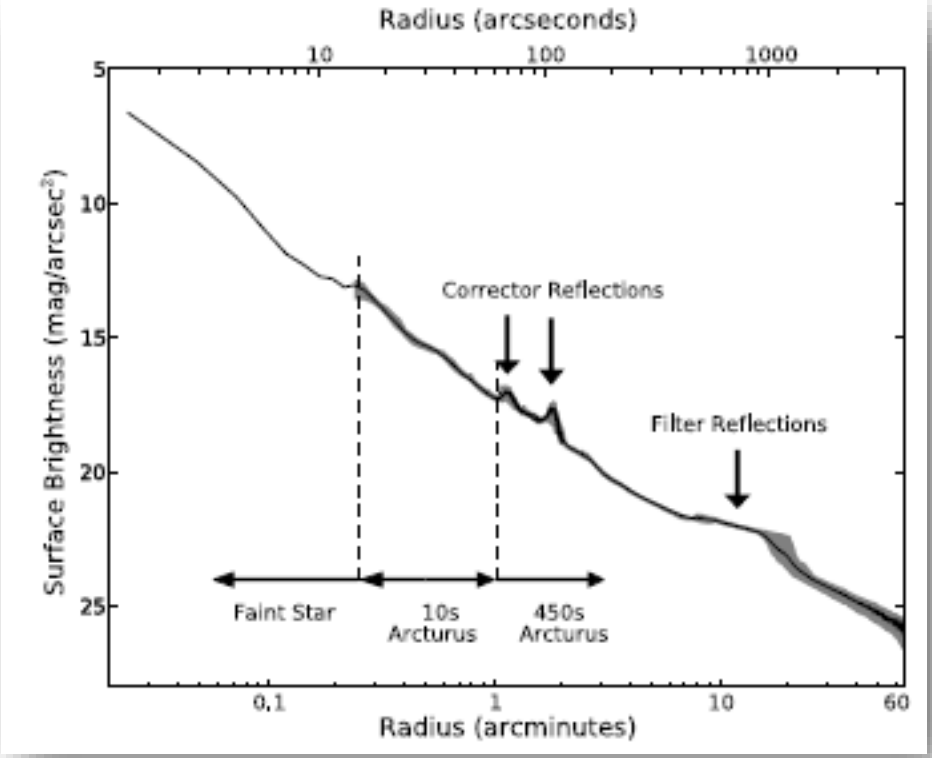


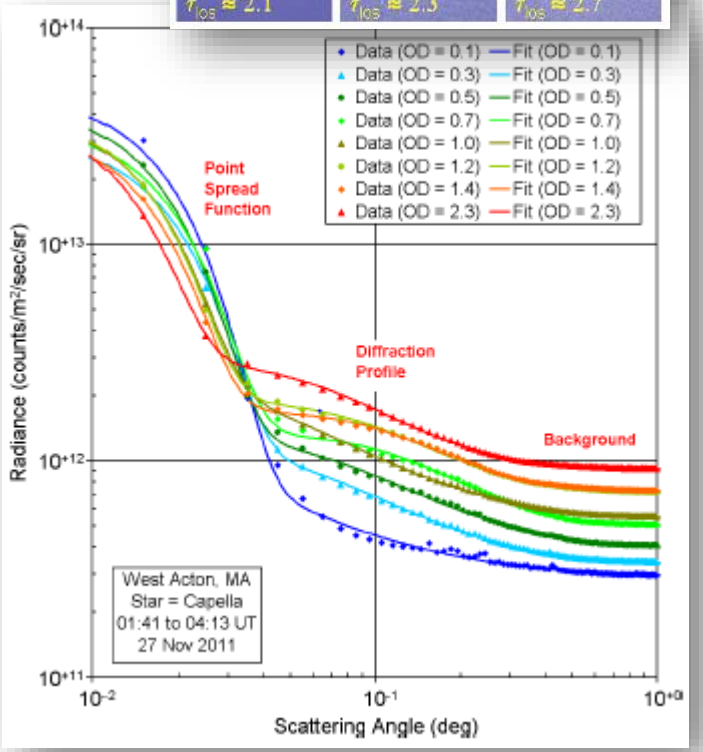
1. [2021−23] LSB optimized telescope development

LSB telescope project: difficulties with LSB imaging

- Large scale flat-fielding issue
- Sky background subtraction/variation
- Telescope PSF, internal reflection, scattering
- Stellar aureole
- Galactic cirrus
- etc.







Summary

- Why exploring the LSB Universe? → **almost totally unknown!**

- Activities for the **LSB Universe exploration**

  - Observations:
    - ICL(high-z, mid-z, low-z)
    - dwarfs around giant galaxies

  - Simulations:
    - ICL/UDG origin

  - Developing Telescope optimized to explore the LSB Universe