Impact of blending on weak lensing measurements with Rubin-LSST

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Scientific context
Cosmology with galaxy clusters

Largest gravitationally bound structures in the Universe

- Size of 1 Mpc
- 50 to 1000 galaxies
- $M > 10^{13.5} M_\odot$, $z < 3$

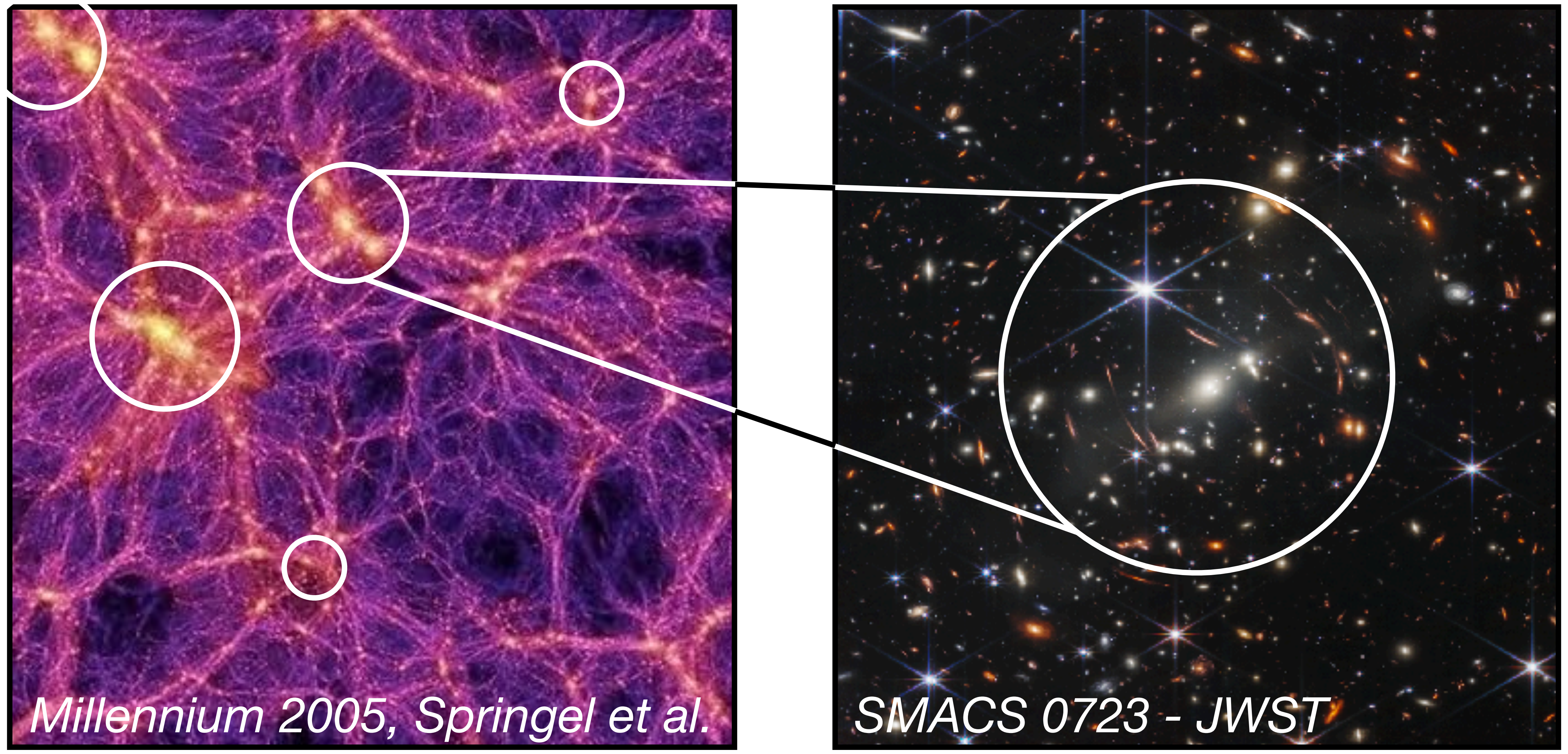
Tracers of the matter over-densities

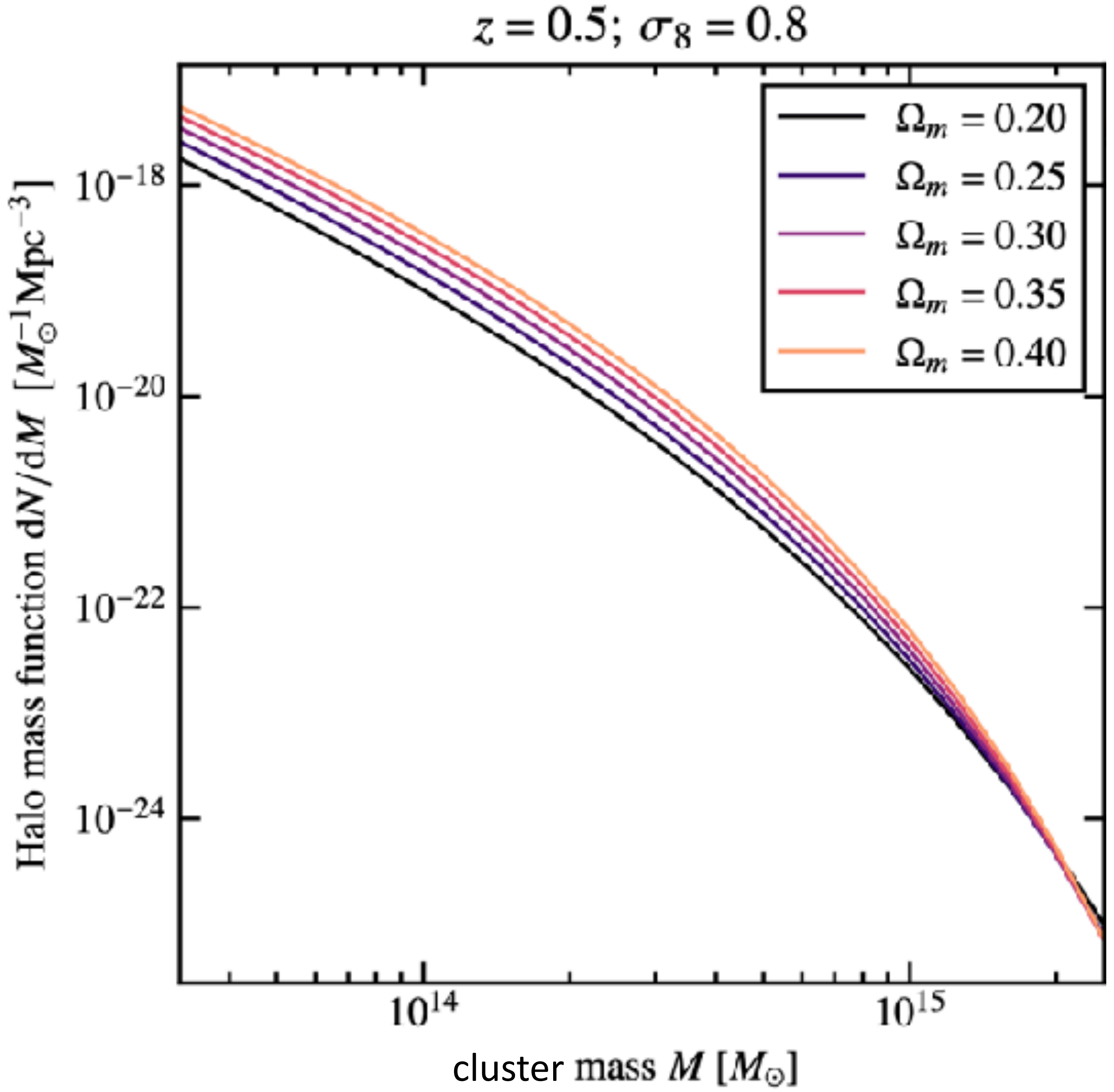
- Abundance depends on cosmology

Studied through their counting per bins of mass and redshift

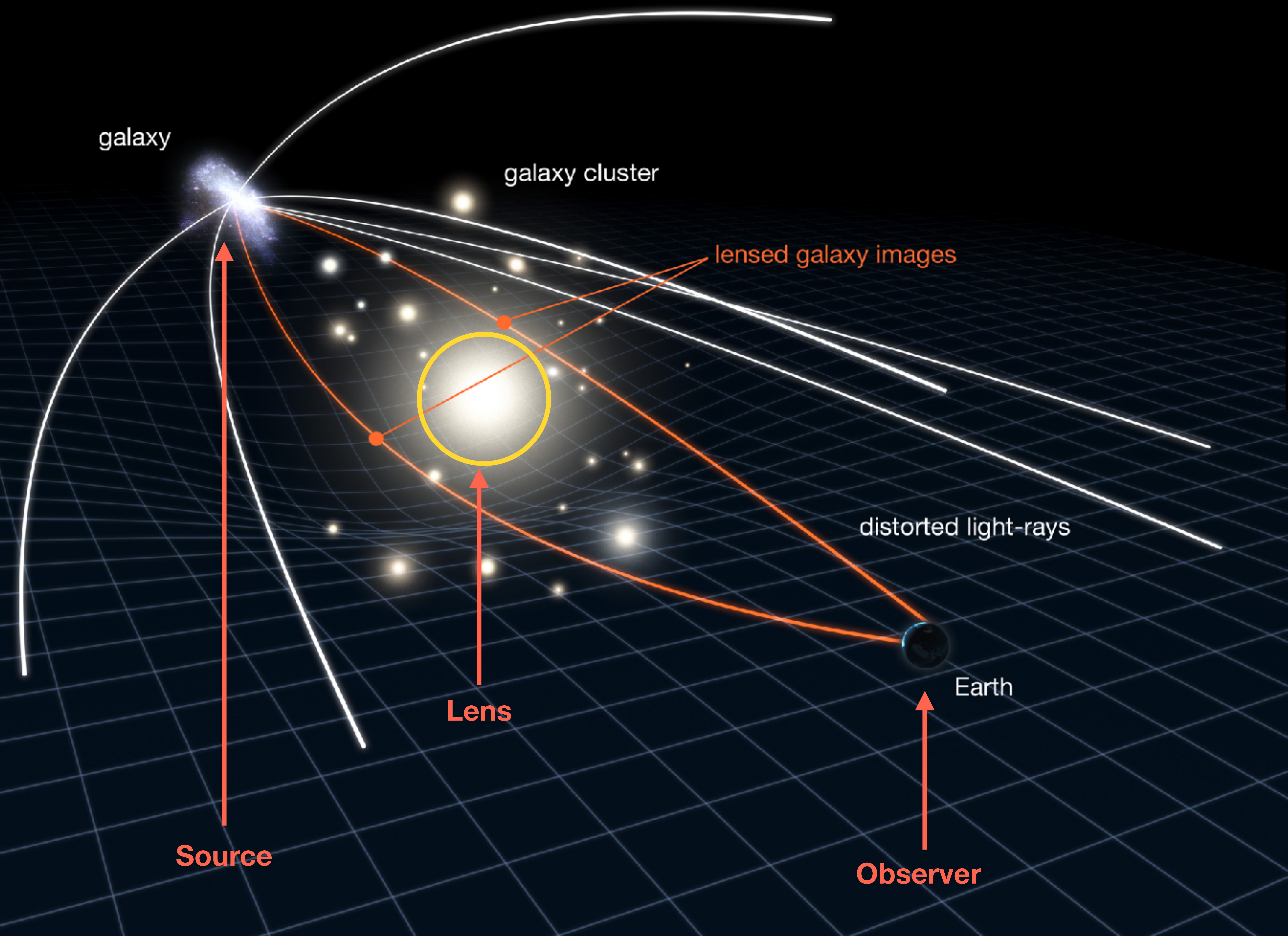
$$\frac{\partial^2 N_{th}}{dz dm} \propto \frac{dn(m,z)}{dm} \frac{d^2V(z)}{dz d\Omega}$$

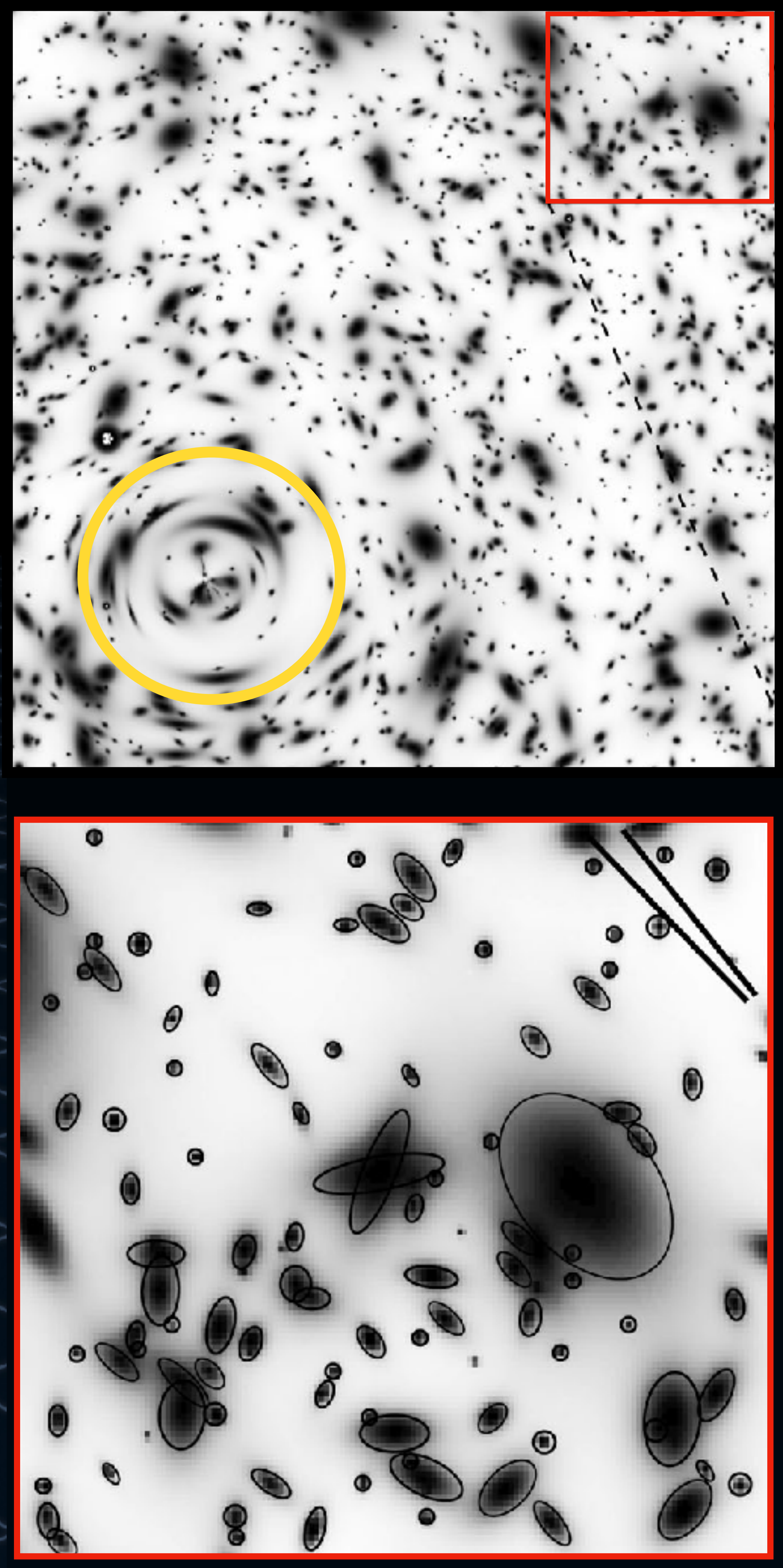
Mass is not an observable:
indirect measurements through weak lensing





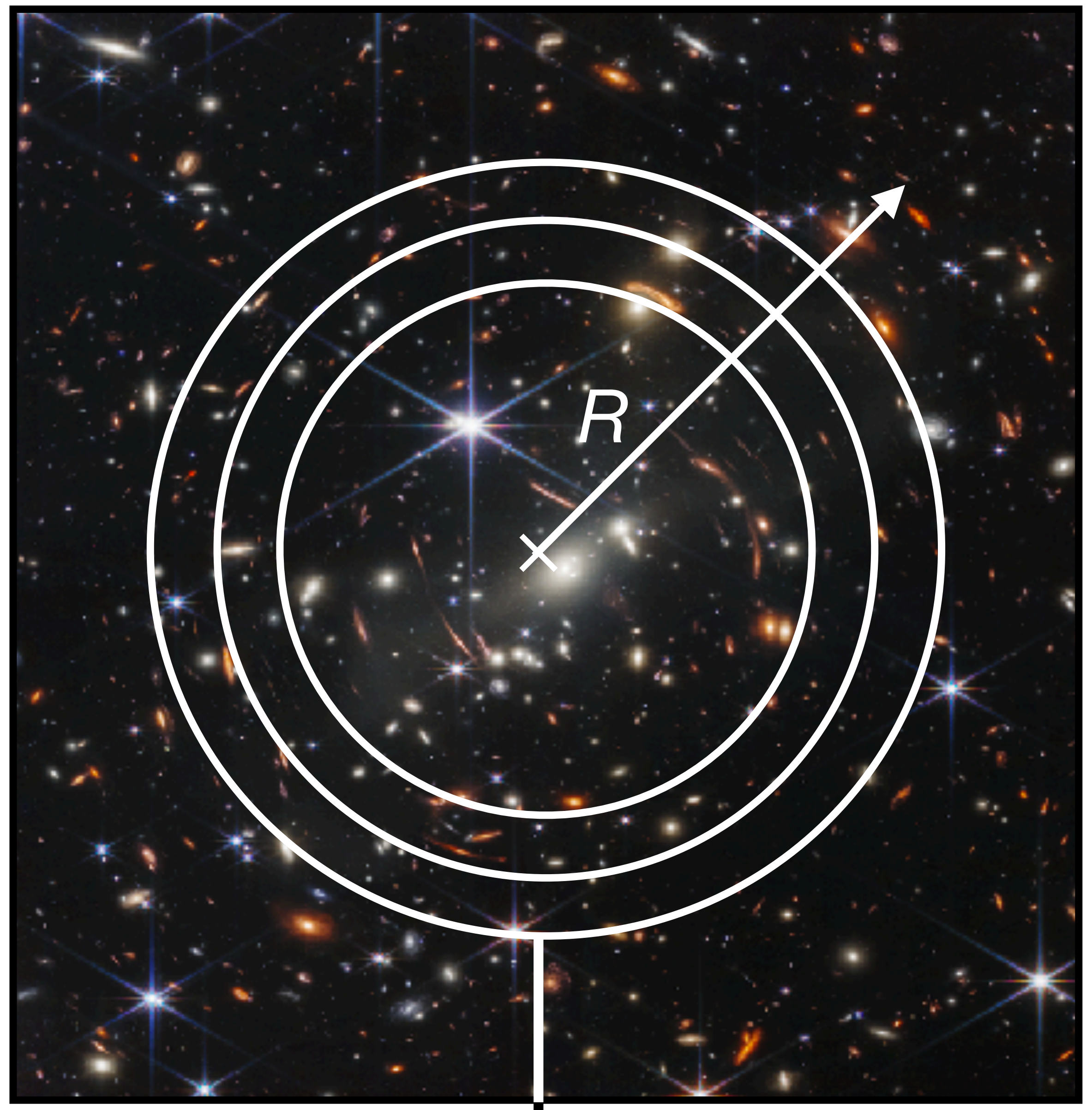
Weak gravitational lensing





Cluster mass from lensing profile

Fit of the lensing profile = estimate of the galaxy cluster mass



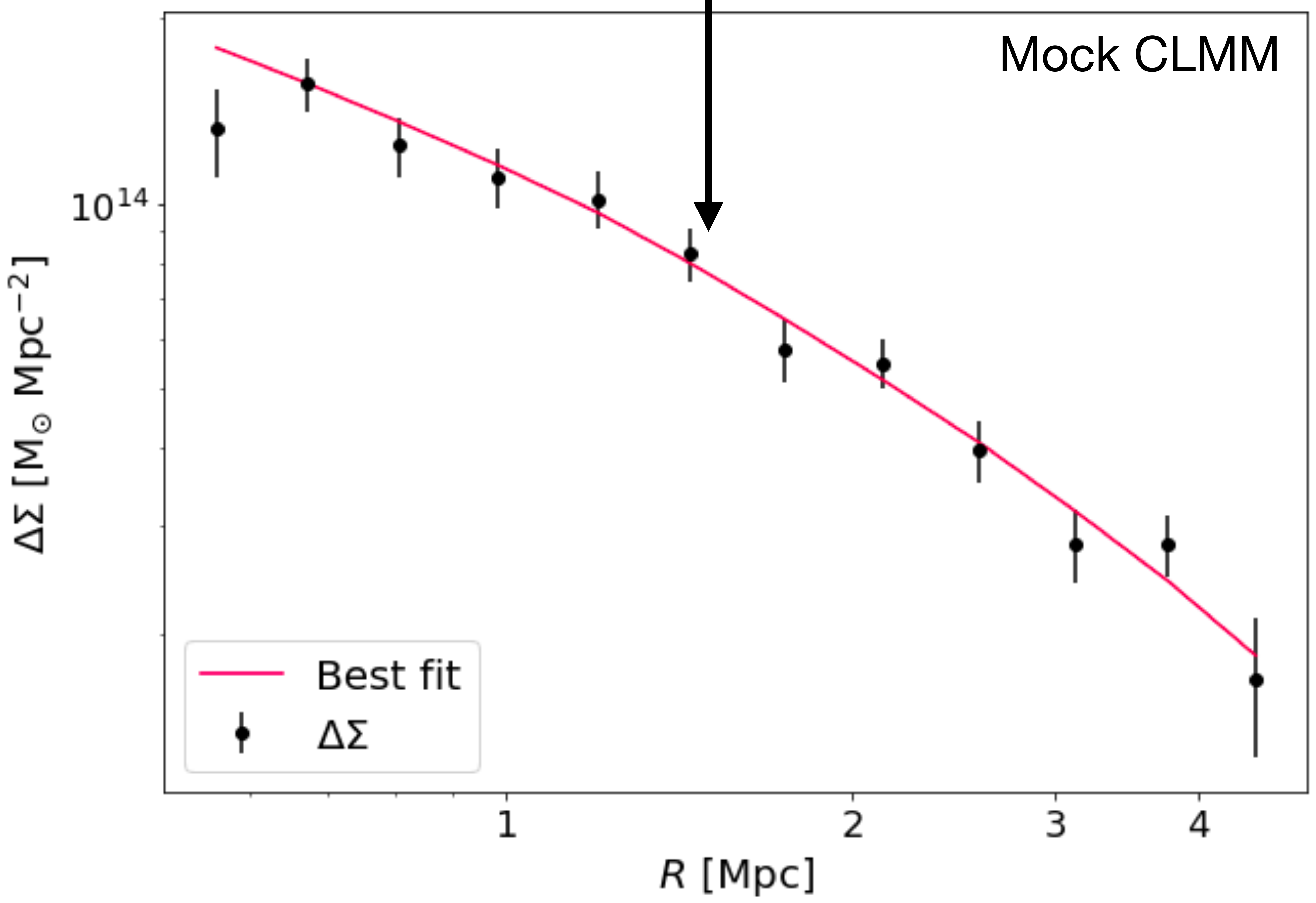
- Excess surface mass density (in $\mathrm{M}_{\odot}\,.\,\mathrm{Mpc}^{-2}$)

$$\widehat{\Delta\Sigma}(R, z_l) = \langle \underbrace{\Sigma_{crit}(z_{gal}, z_l)}_{\text{Critical surface mass density}} \ \underbrace{\epsilon_{+}^{obs}}_{\text{Tangential ellipticity}} \rangle$$

Average on many galaxies

Critical surface mass density → needs **redshifts**

Tangential ellipticity → needs **shapes**



Vera C. Rubin - LSST

LSST DESC
Dark Energy Science Collaboration

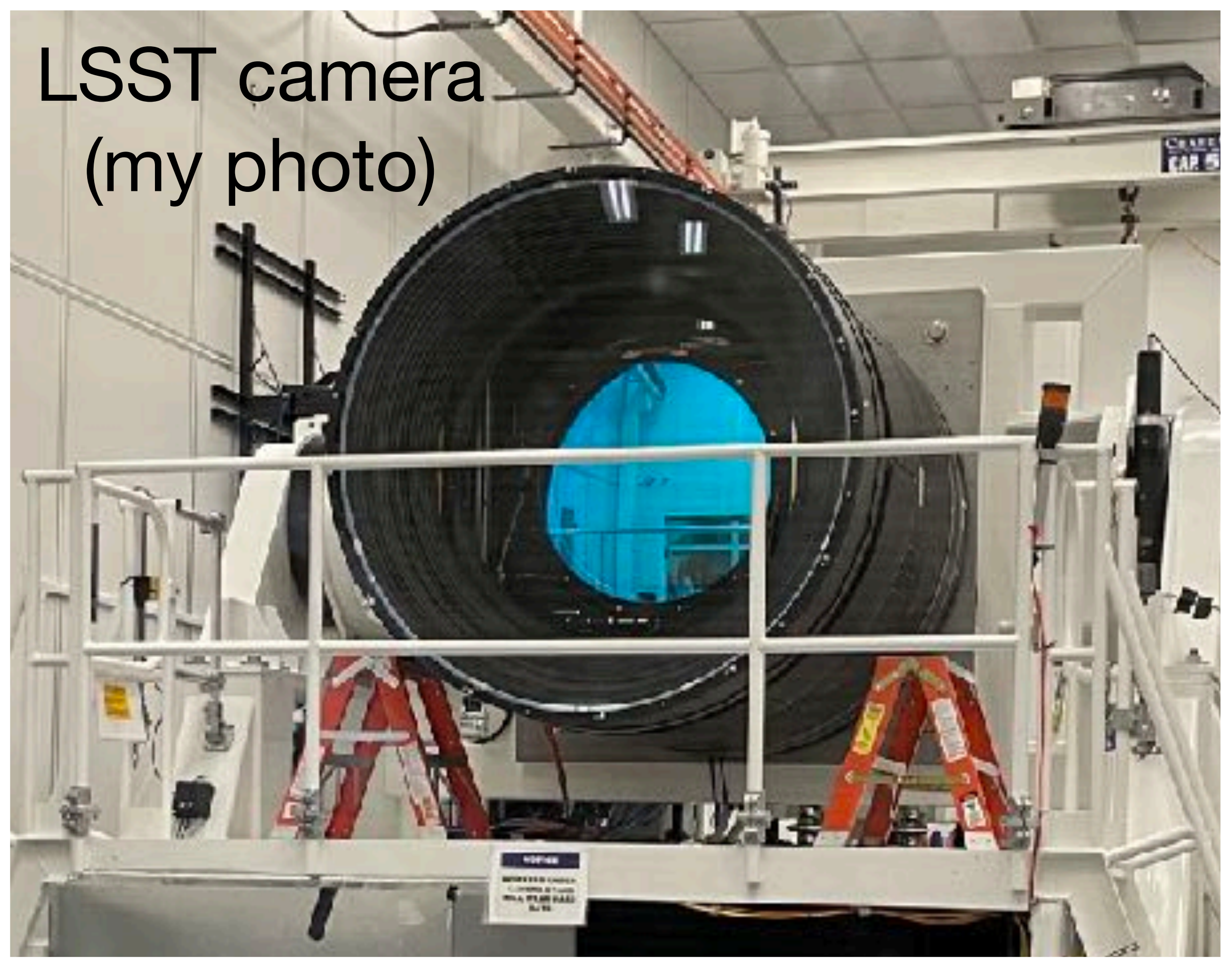
Vera C. Rubin Observatory

- World's largest camera (3 billions pixels)

Legacy Survey of Space and Time - LSST

- **Optical** and **deep** sky survey over 10 years
- First scientific data in **2025**

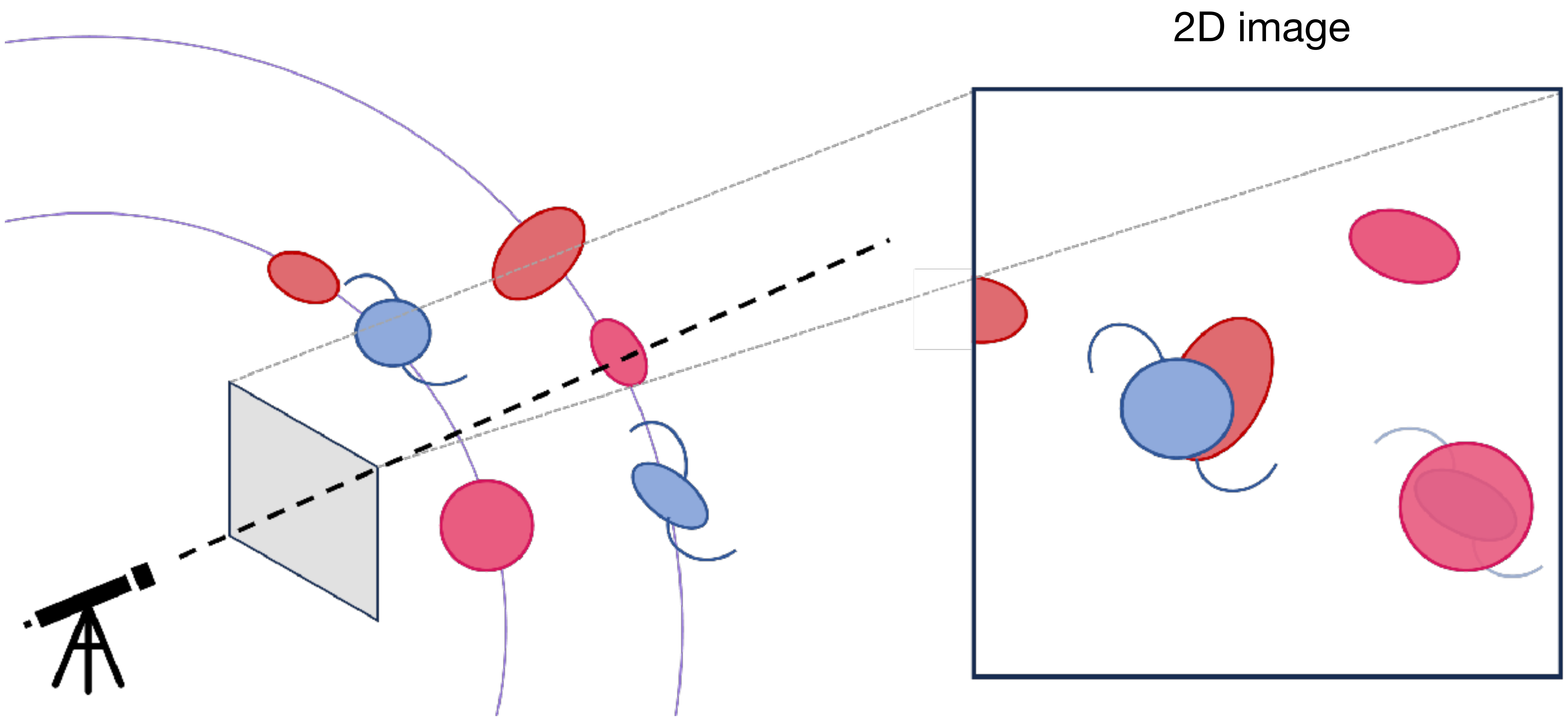
Survey	Sky area (deg^2)	# of galaxies	Limit magnitude
LSST	18,000	10^{10}	27.5
DES	5,000	7.10^{8}	24.5
HSC	1,400	10^{7}	26


LSST camera (my photo)

Blending

Superposition of galaxies due to:

- The **depth** of observation
- The survey's **resolution**



Blending

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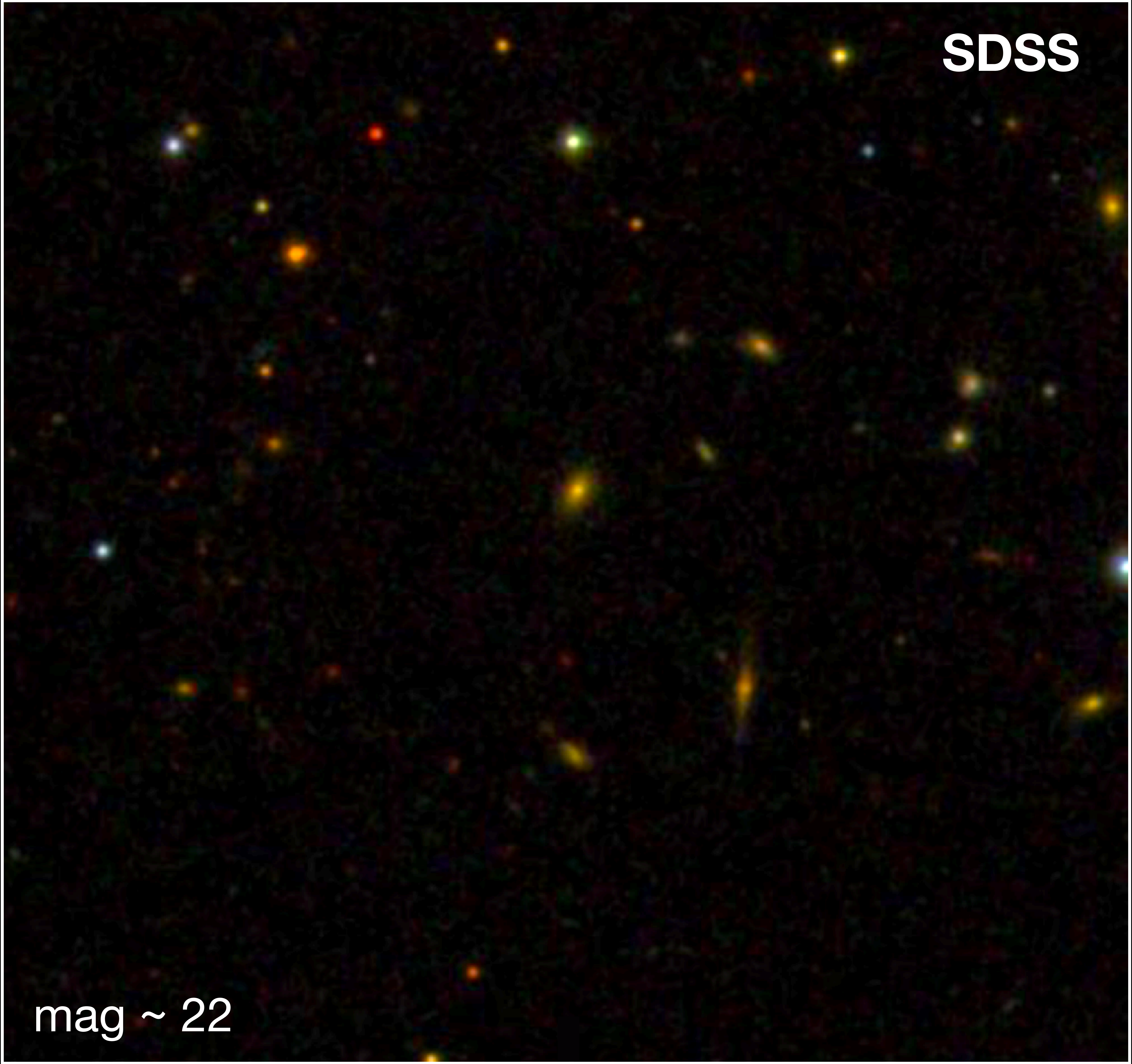

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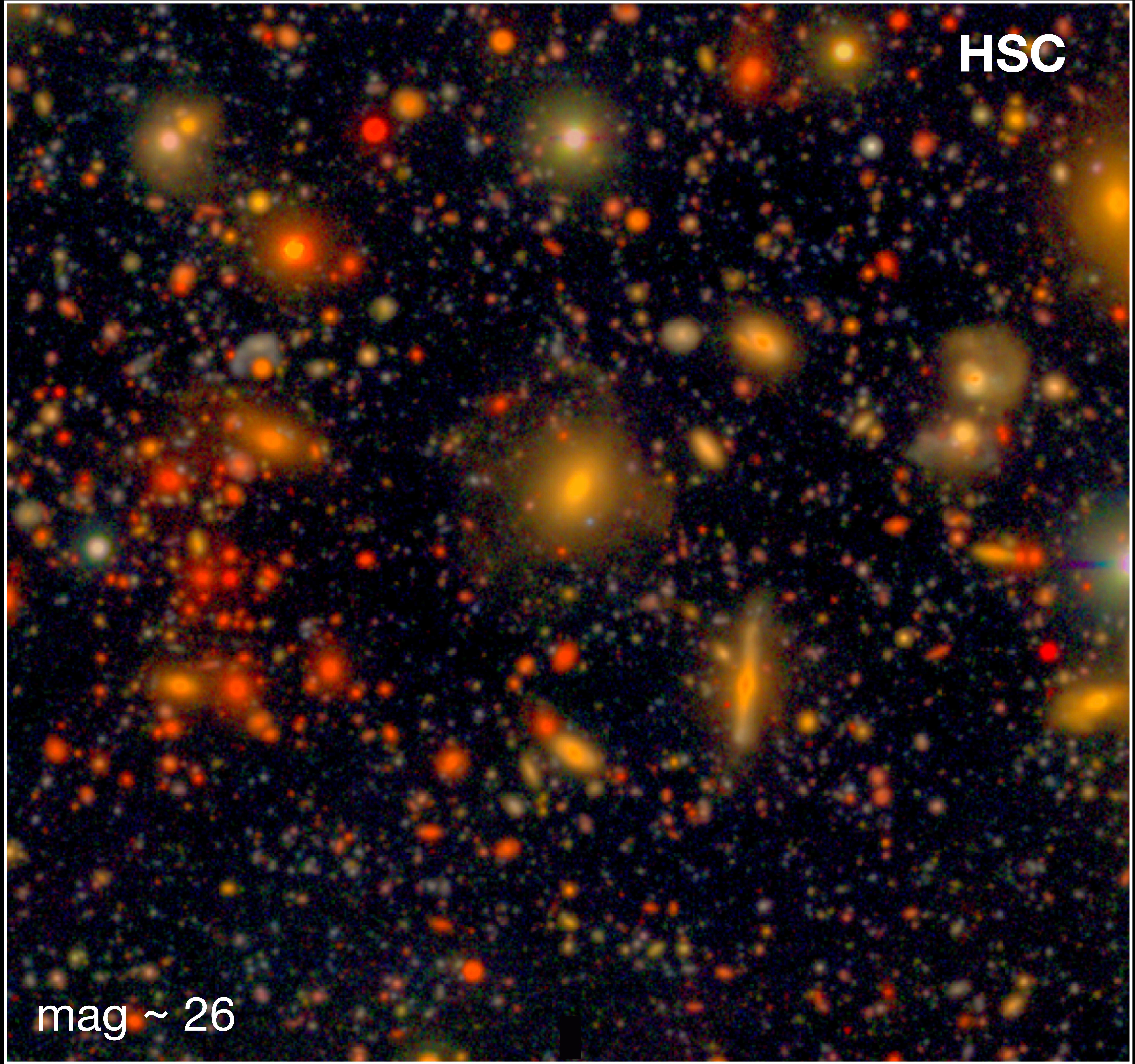

Blending

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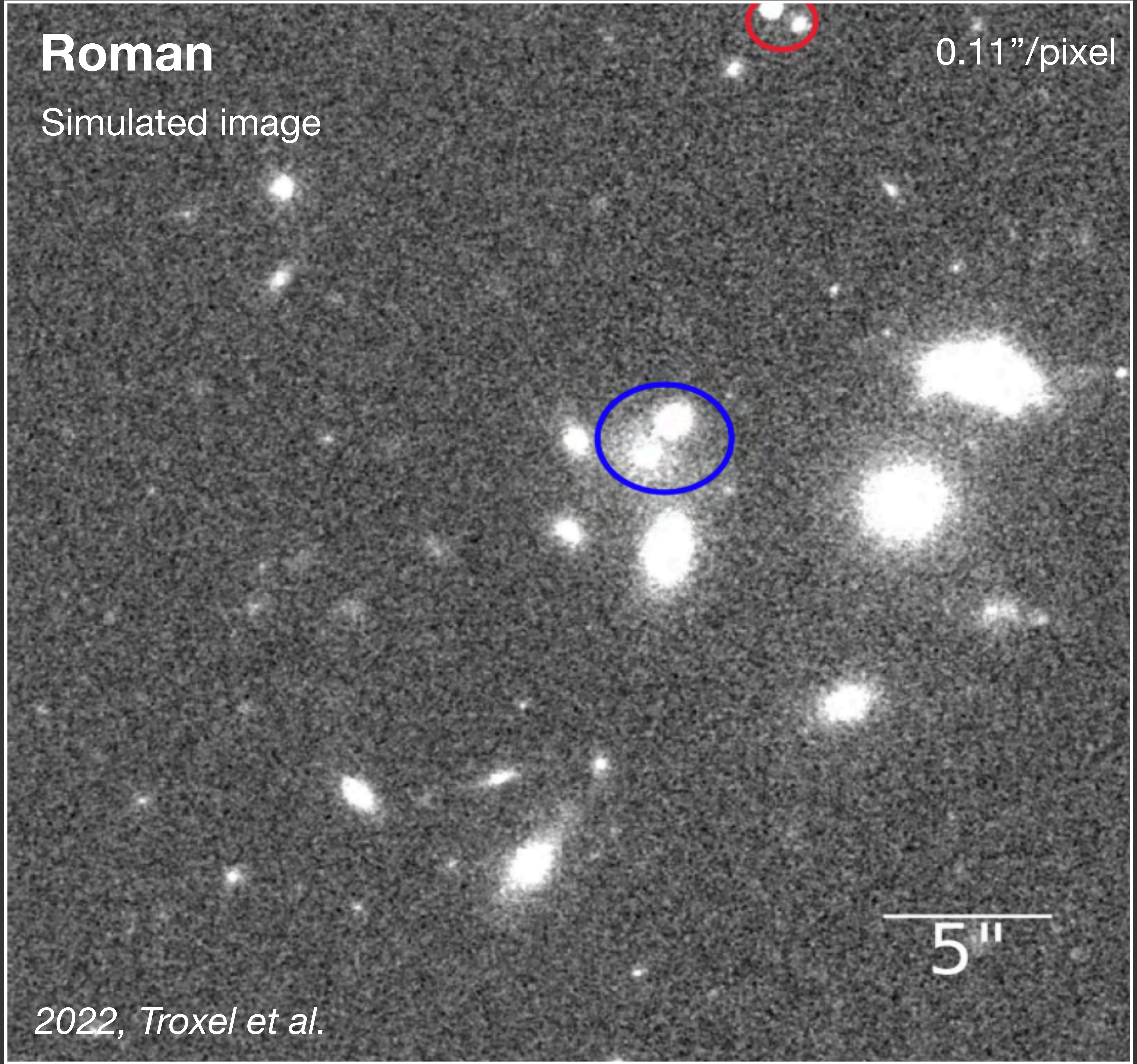

Blending

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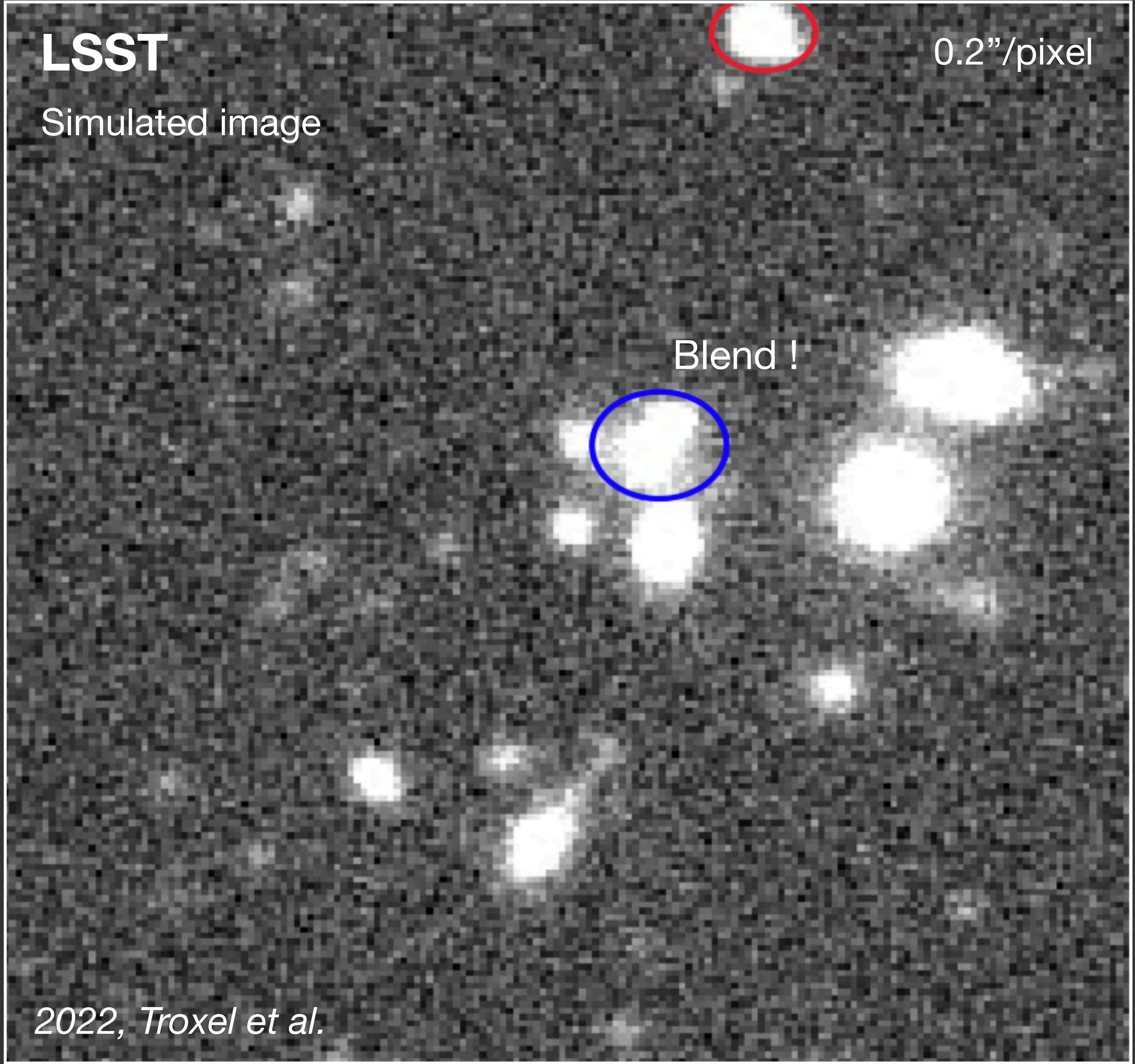
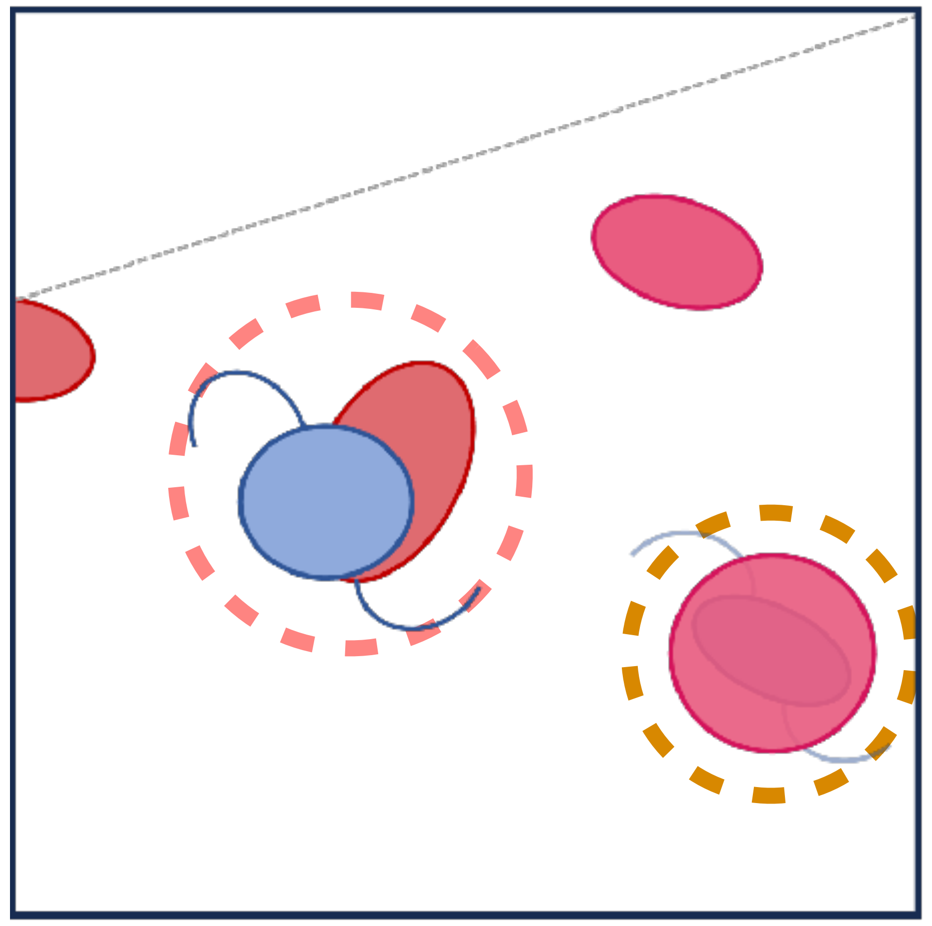


Blending

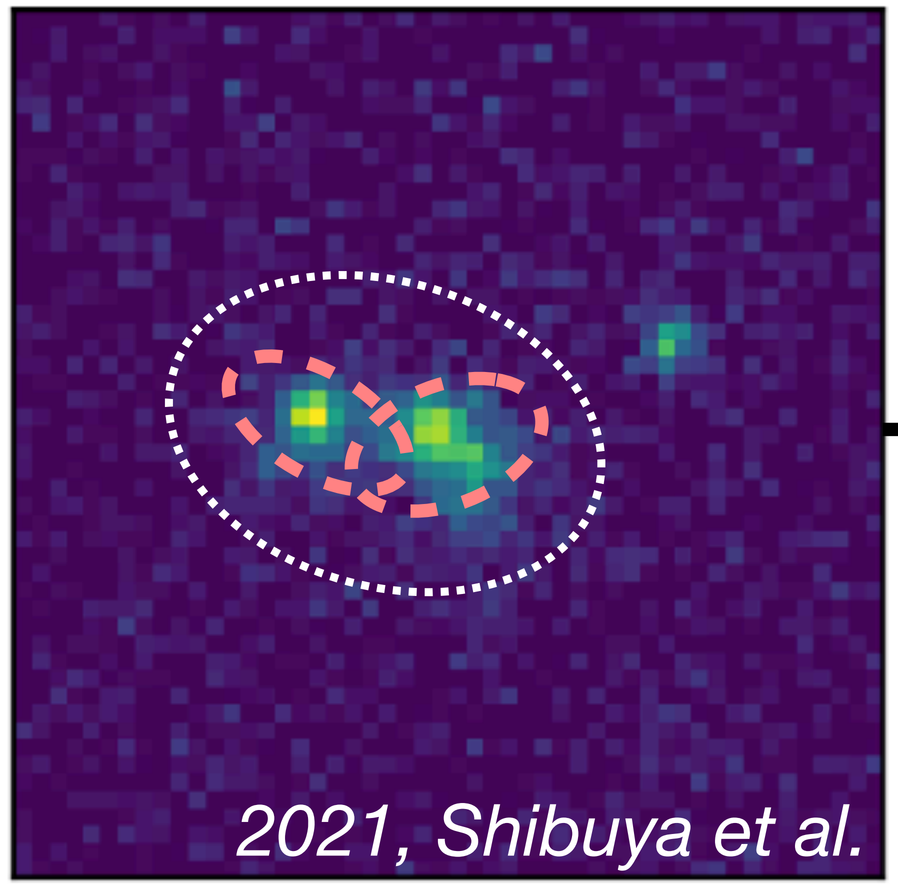
2D image



Less resolution

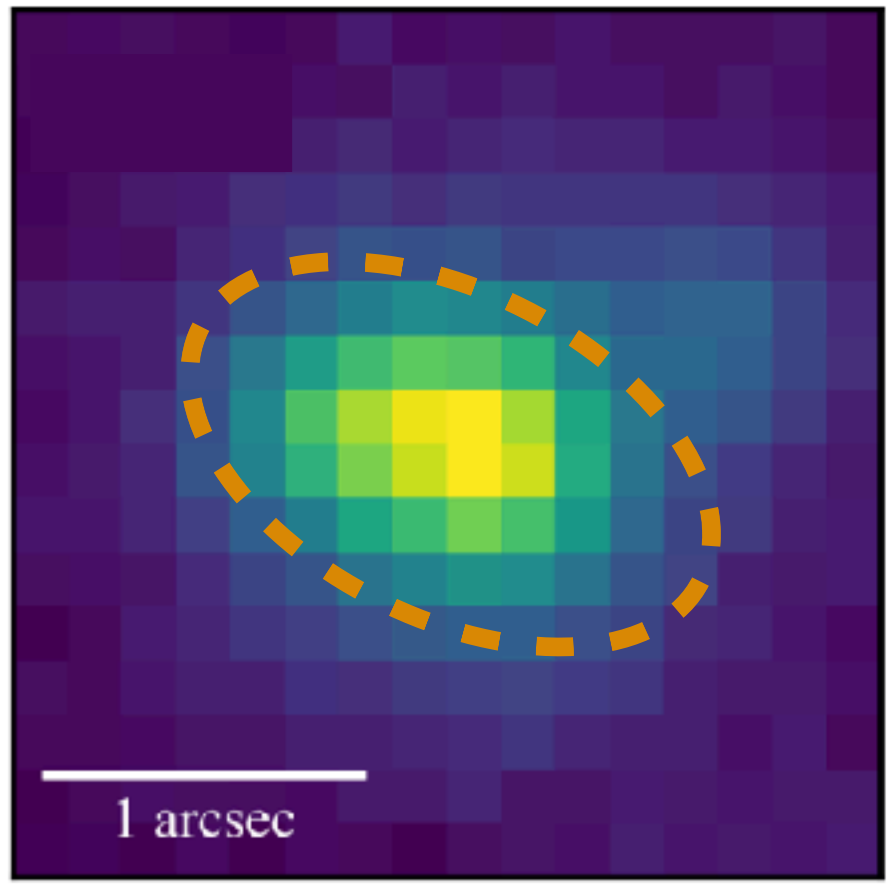
Recognized blends

Hubble/ACS

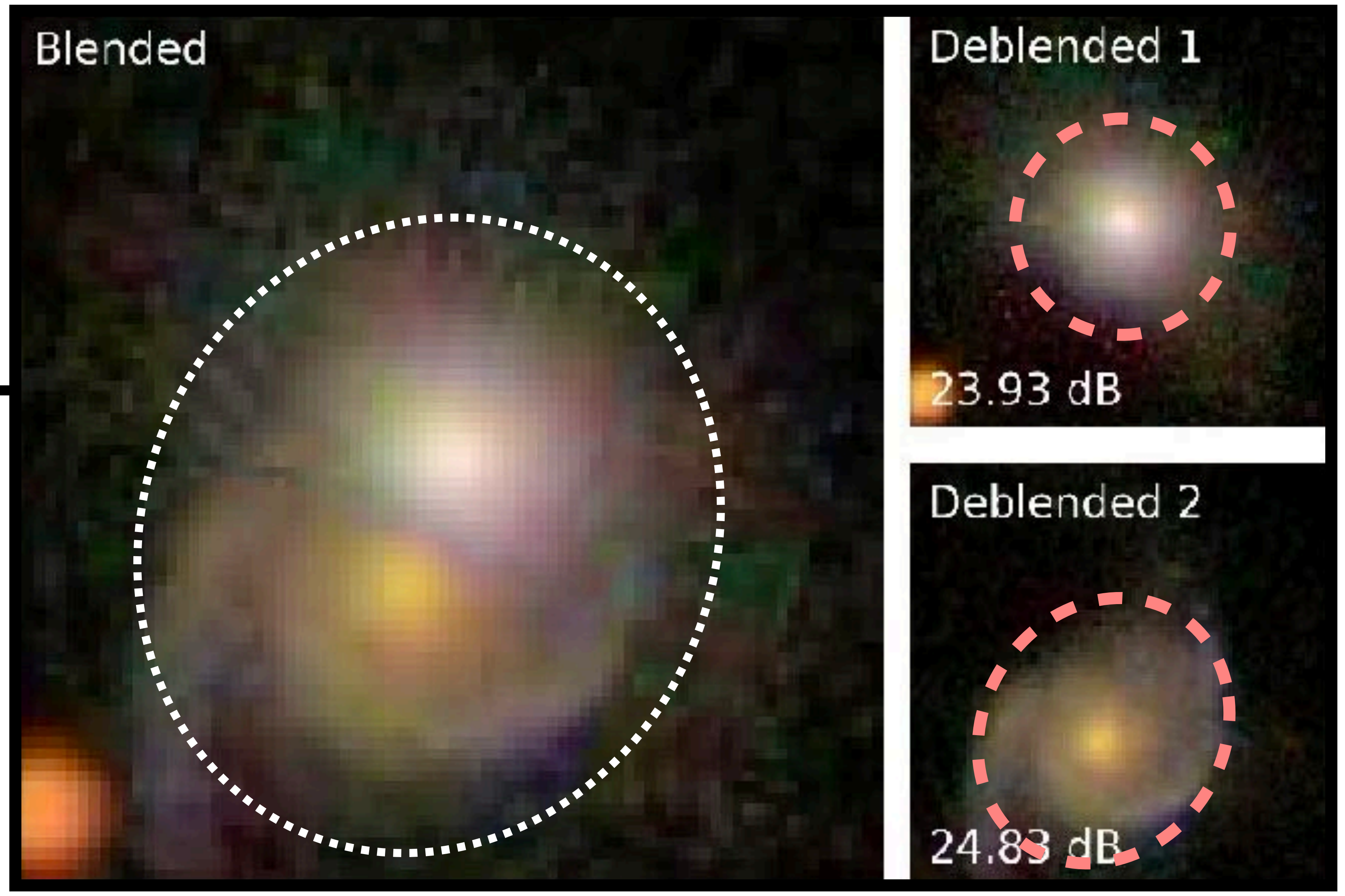


Unrecognized blends

Subaru/HSC



LSST deblender: **SCARLET**



LSST ~ 60% of blends

- Recognized blends: **~40 %**
- Unrecognized blends: **~14 - 20 %***

DES ~ 10% of blends

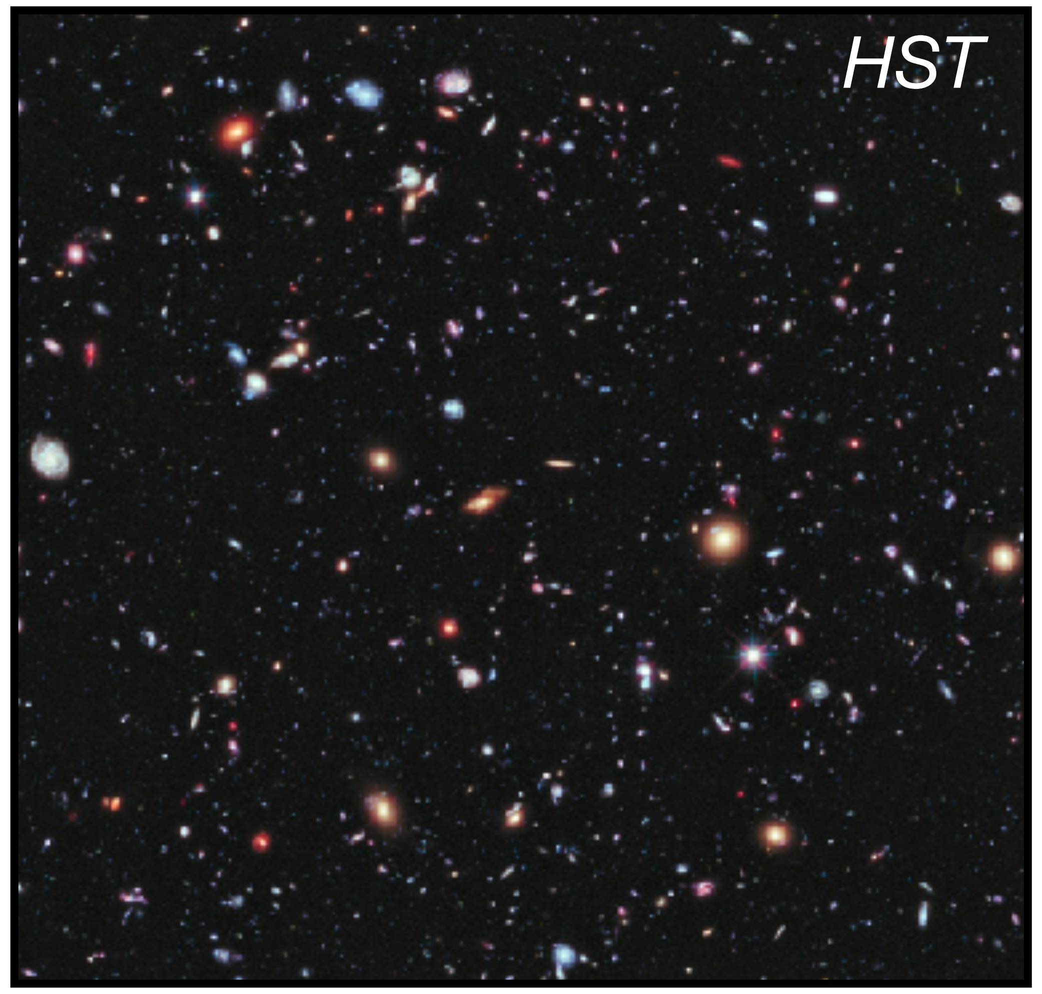
* *2016, Dawson et al.*
2022, Troxel et al.

Blending around galaxy clusters

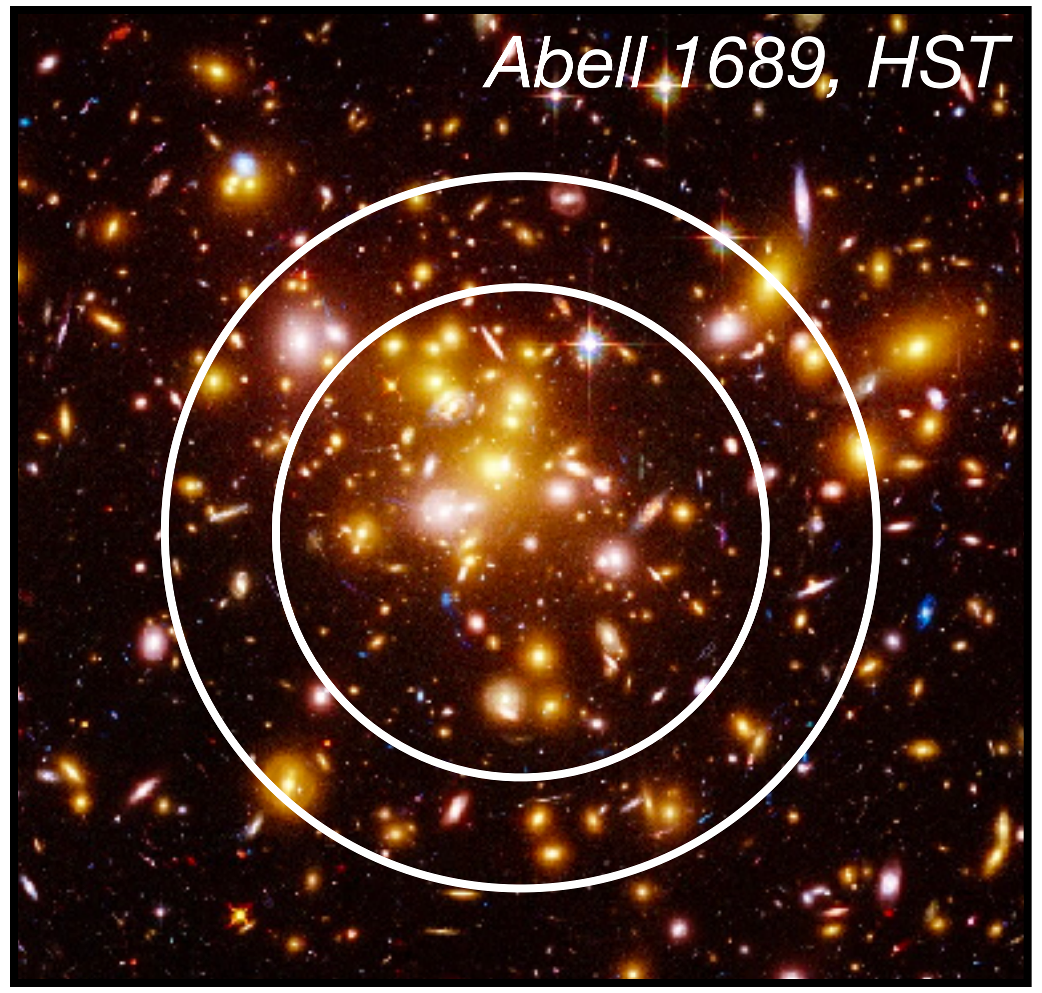
Galaxy clusters = high density regions = **blending**

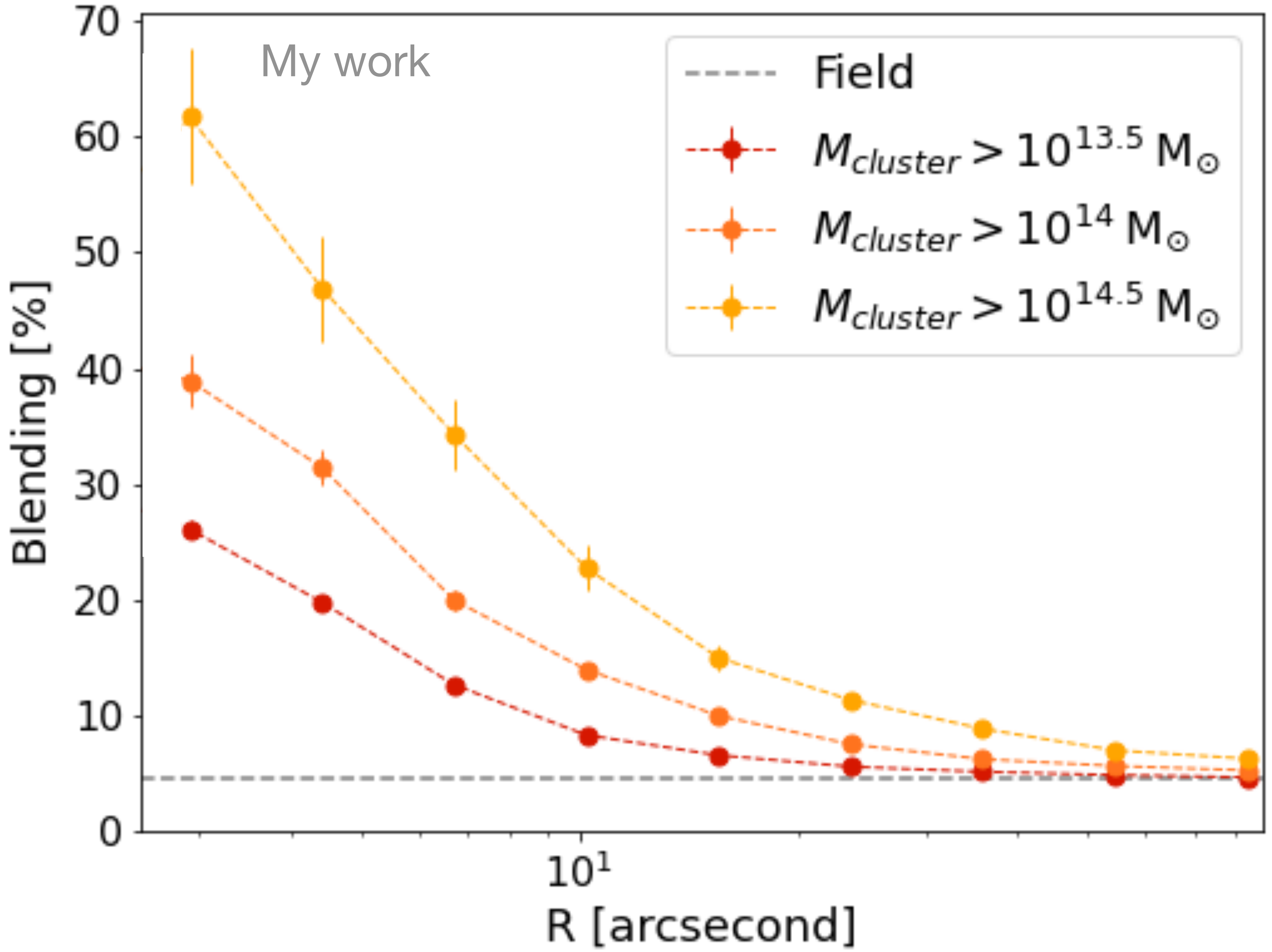
High amount of blending near clusters centres

FIELD



CLUSTER





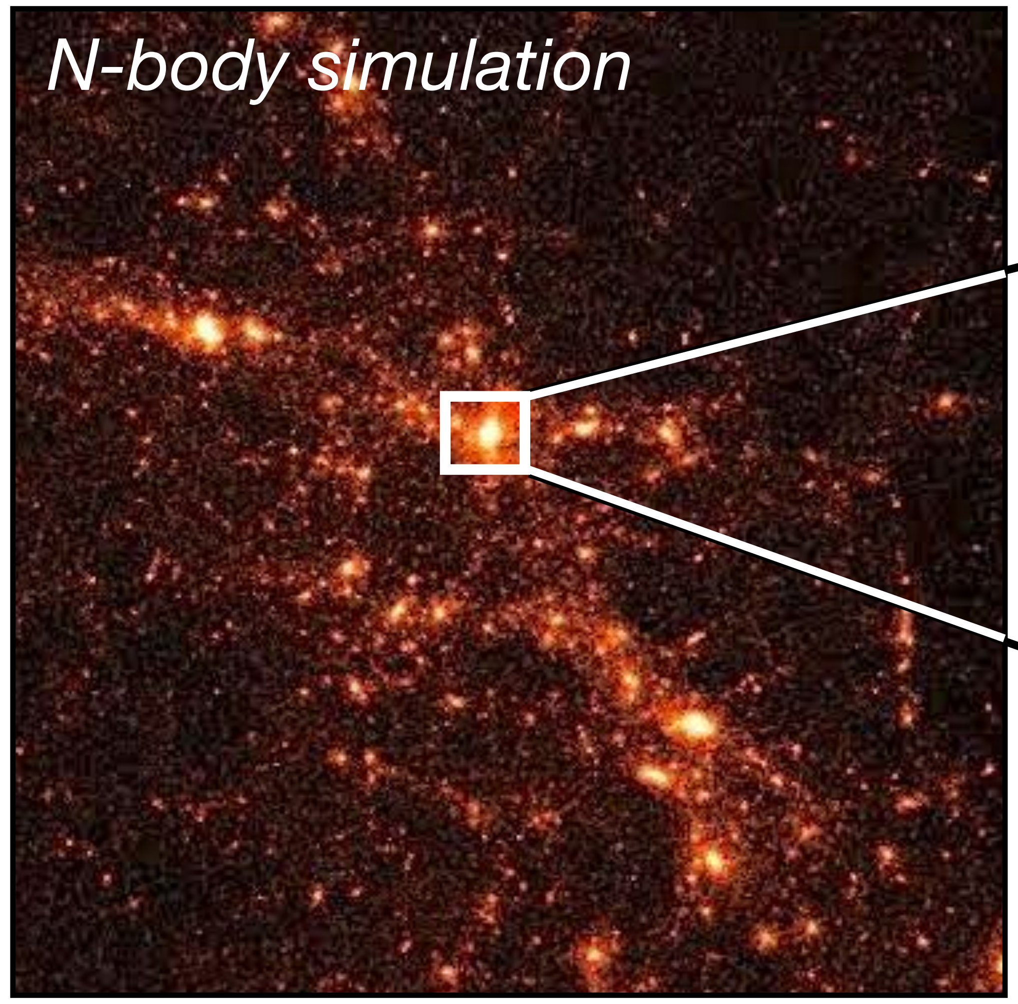
Blending impacts:

- The **detection** of galaxies
- The measurement of **shapes**
- The measurement of **redshifts**

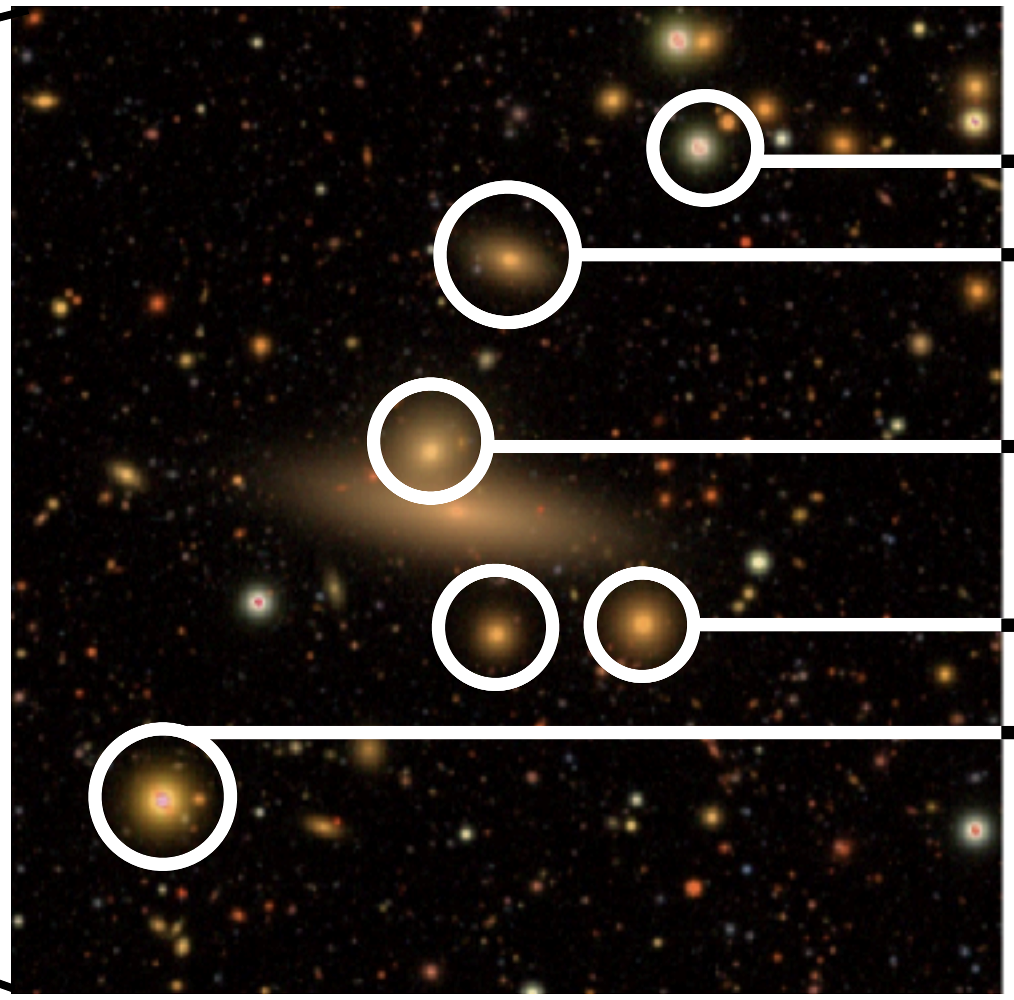
WL profiles ↔ galaxy cluster masses ↔ cosmology

Detection of blends in DESC simulations

Simulated catalogs



Outer Rim 2019, Heitmann et al.



DESC simulated image

mag_i	ra	e1	dec
24.541830	58.200397	-0.141020	-35.702272
26.177008	58.179060	0.173040	-35.702067
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
...	...	...	...
26.582999	56.529076	-0.210661	-34.322543
27.233892	56.628691	-0.630063	-34.278873

Observational effects included !

cosmoDC2 = truth catalog

- 440 deg^2 catalog from a N-body simulation
- Reference for **galaxies** and dark matter haloes
- True shapes, magnitudes, positions…

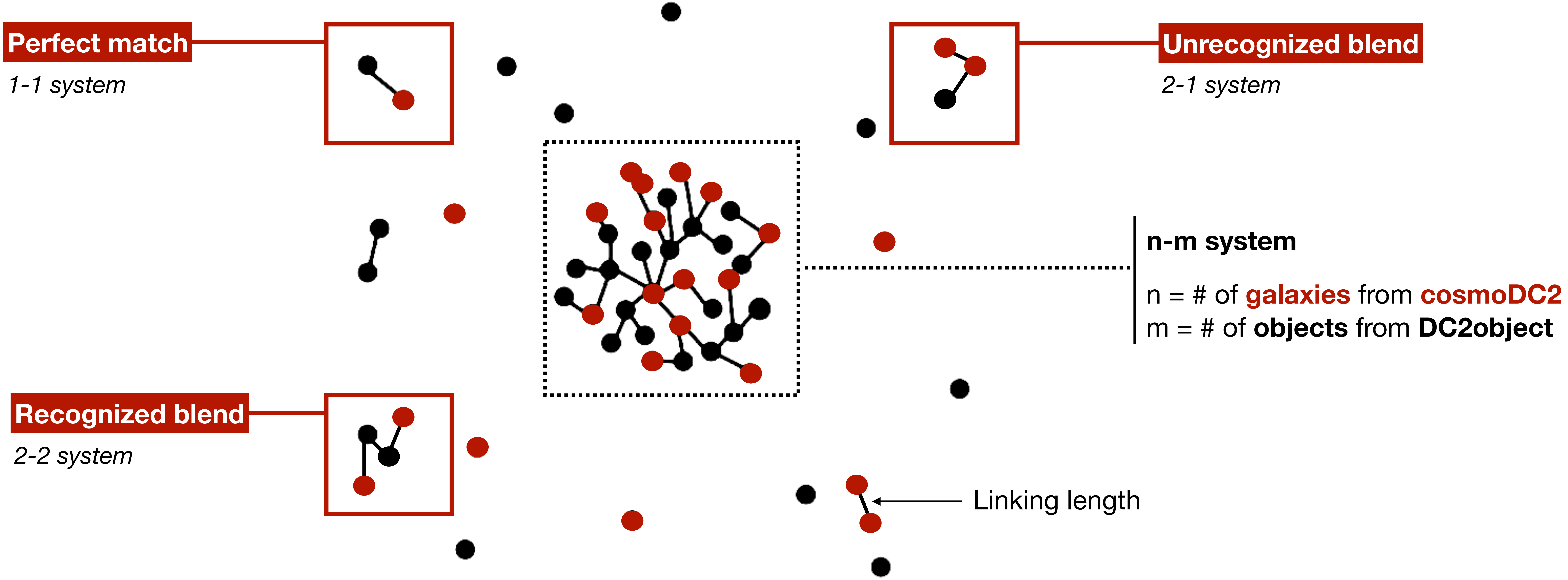
DC2object = object catalog

- Simulated images from cosmoDC2
- Detection of **objects**
- Measured shapes, magnitudes, positions

Identification of blends through catalog matching

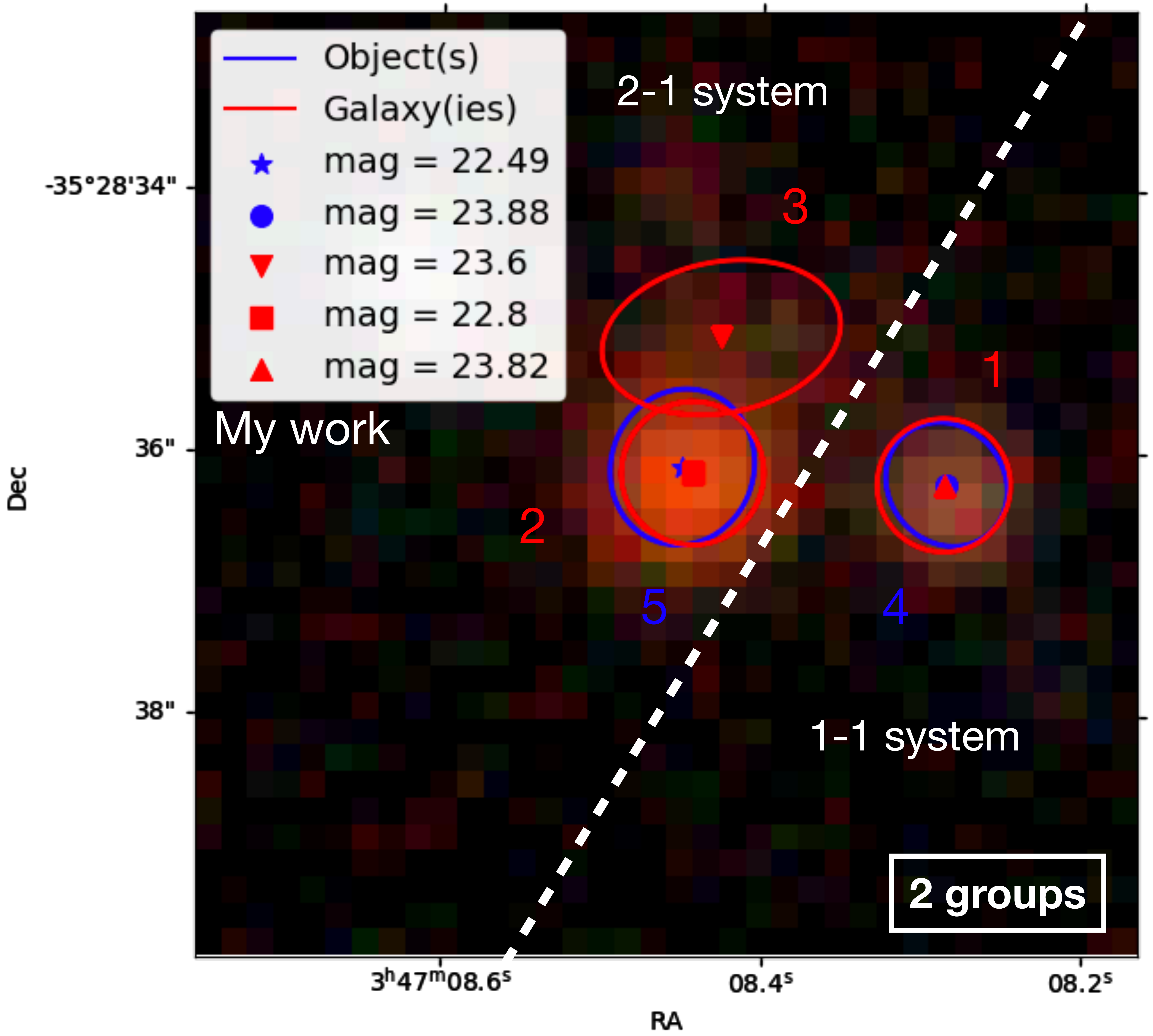
Matching procedure: Friends-of-Friends

https://github.com/yymao/FoFCatalogMatching



Matching procedure: friendly

https://github.com/LSSTDESC/friendly
https://github.com/LSSTDESC/Cluster_Blending



Detection of blends in DESC simulations

Matching procedure: friendly

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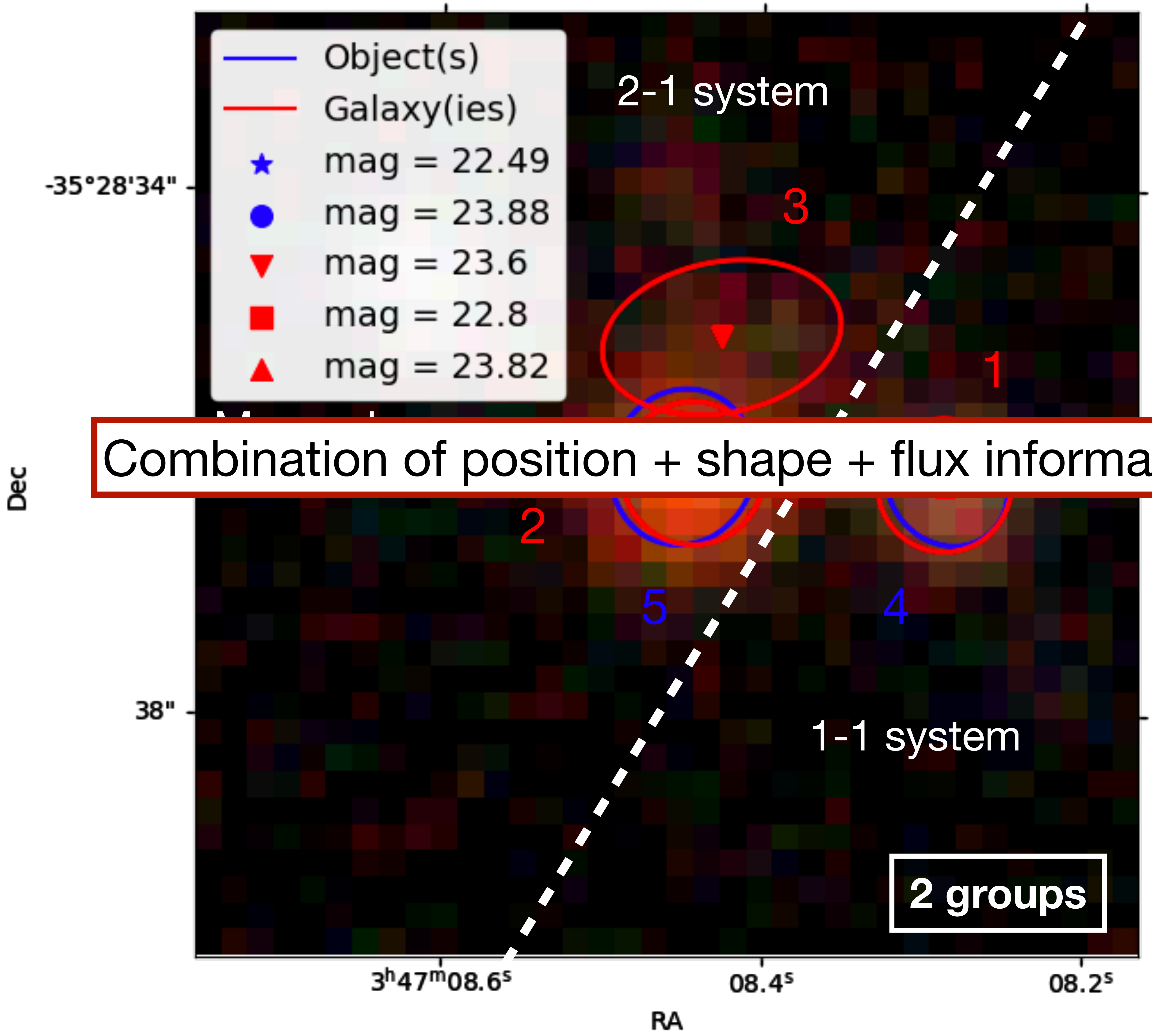
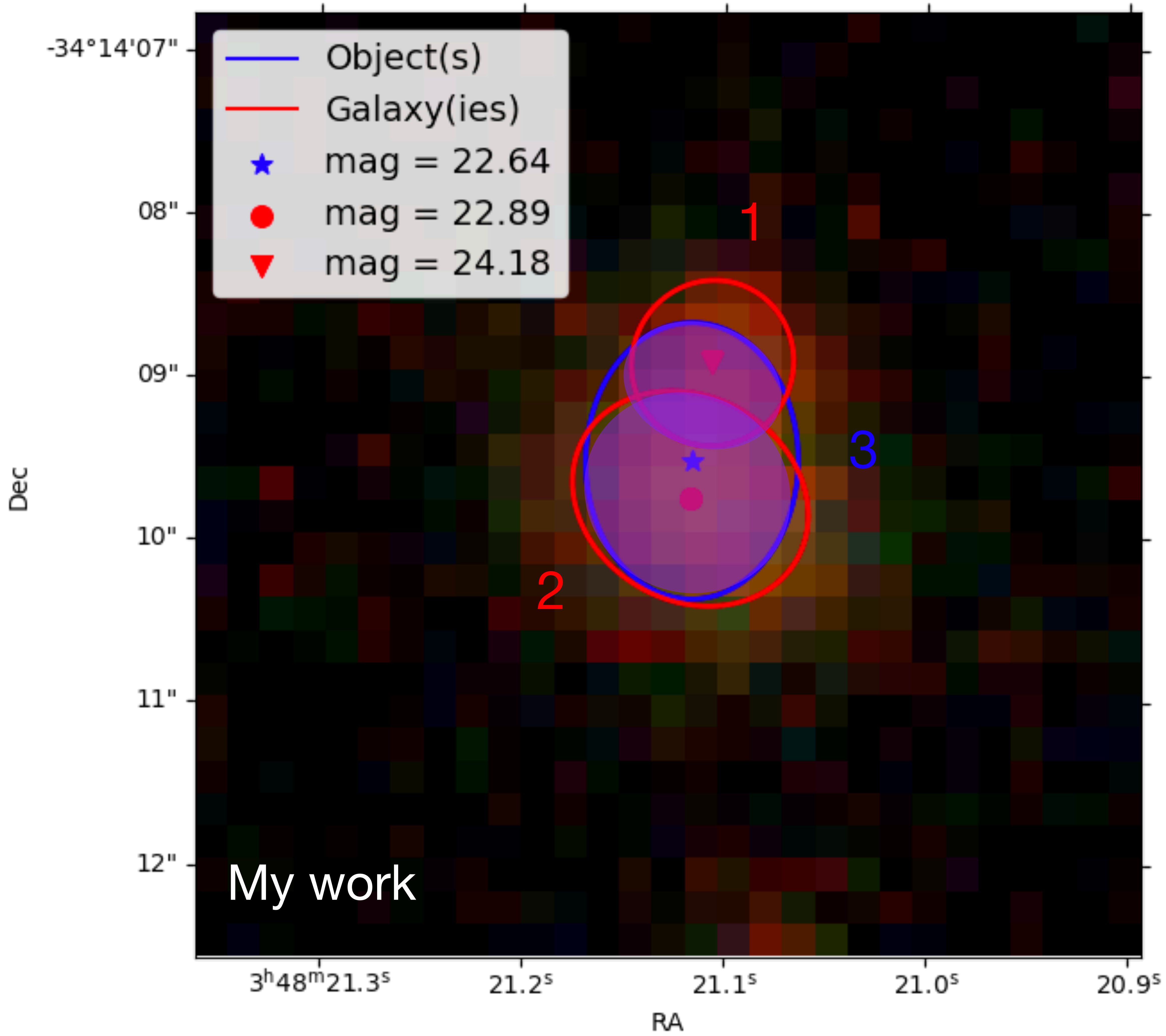


Combination of position + shape + flux information

Relative probabilities of matching galaxies $\longrightarrow$ *See blending as a matching **ambiguity**…*



1. For each object:

   Matching probability with one galaxy of the group

   $p \propto$ overlap weighted by the difference in magnitudes

2. Vector of matching probabilities

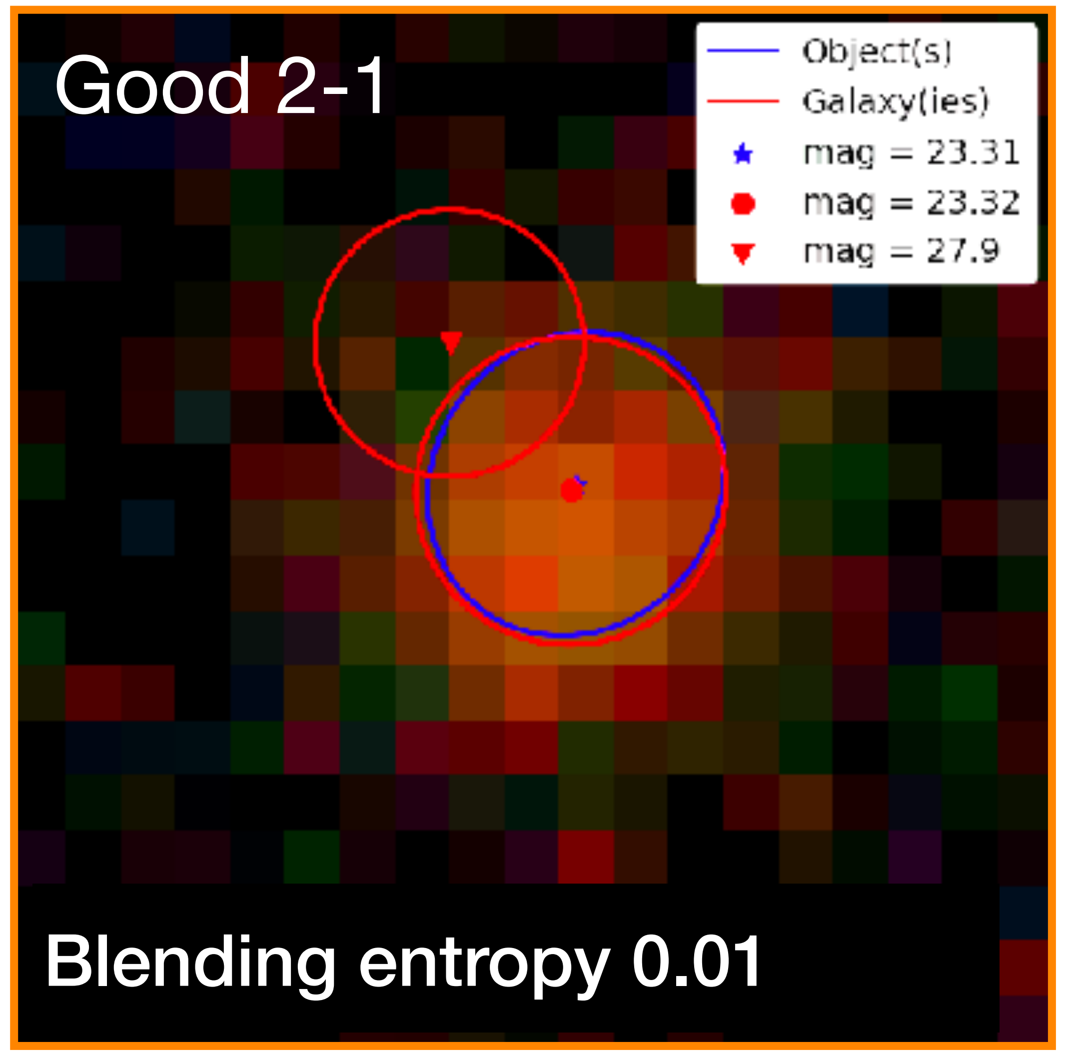
3. Blending entropy:

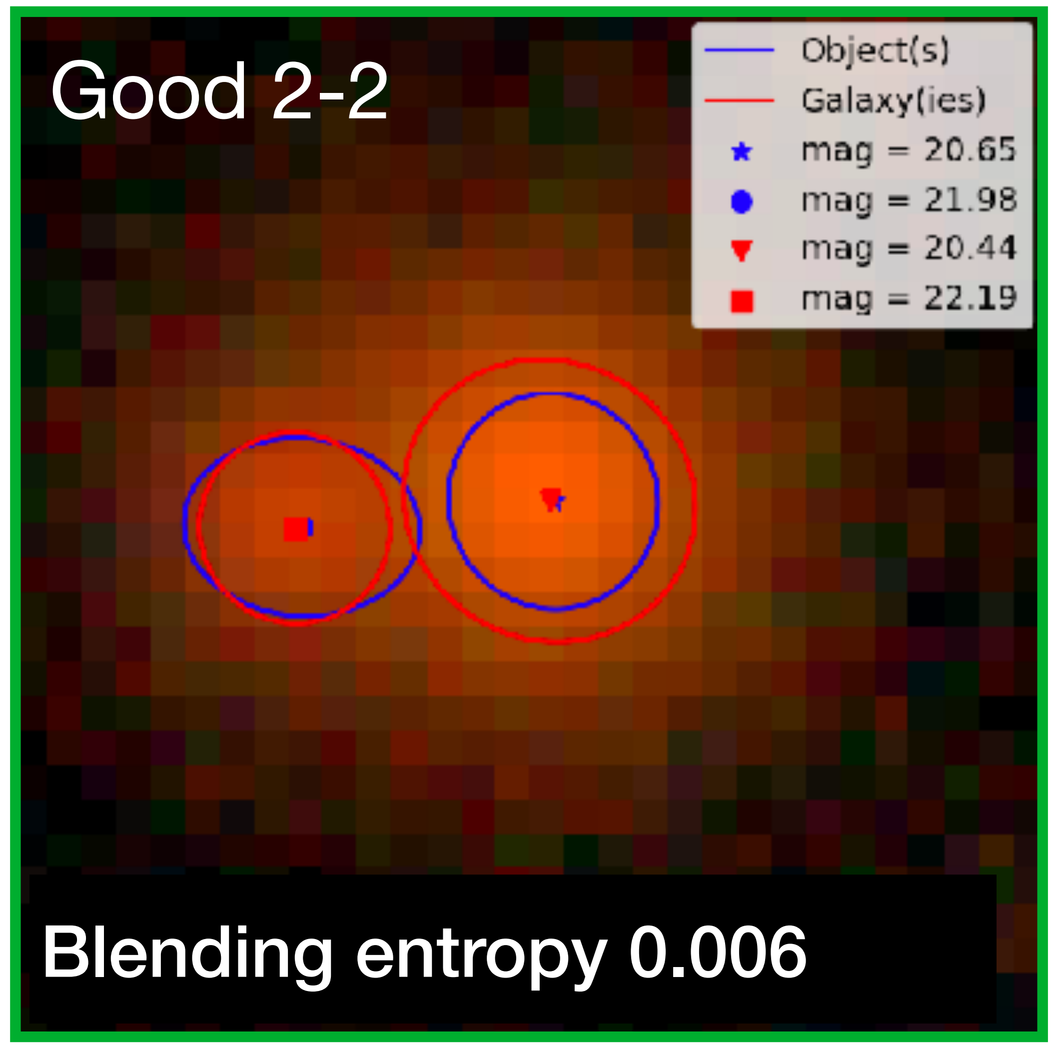
$$S_b = -\sum_i p_i \log p_i$$

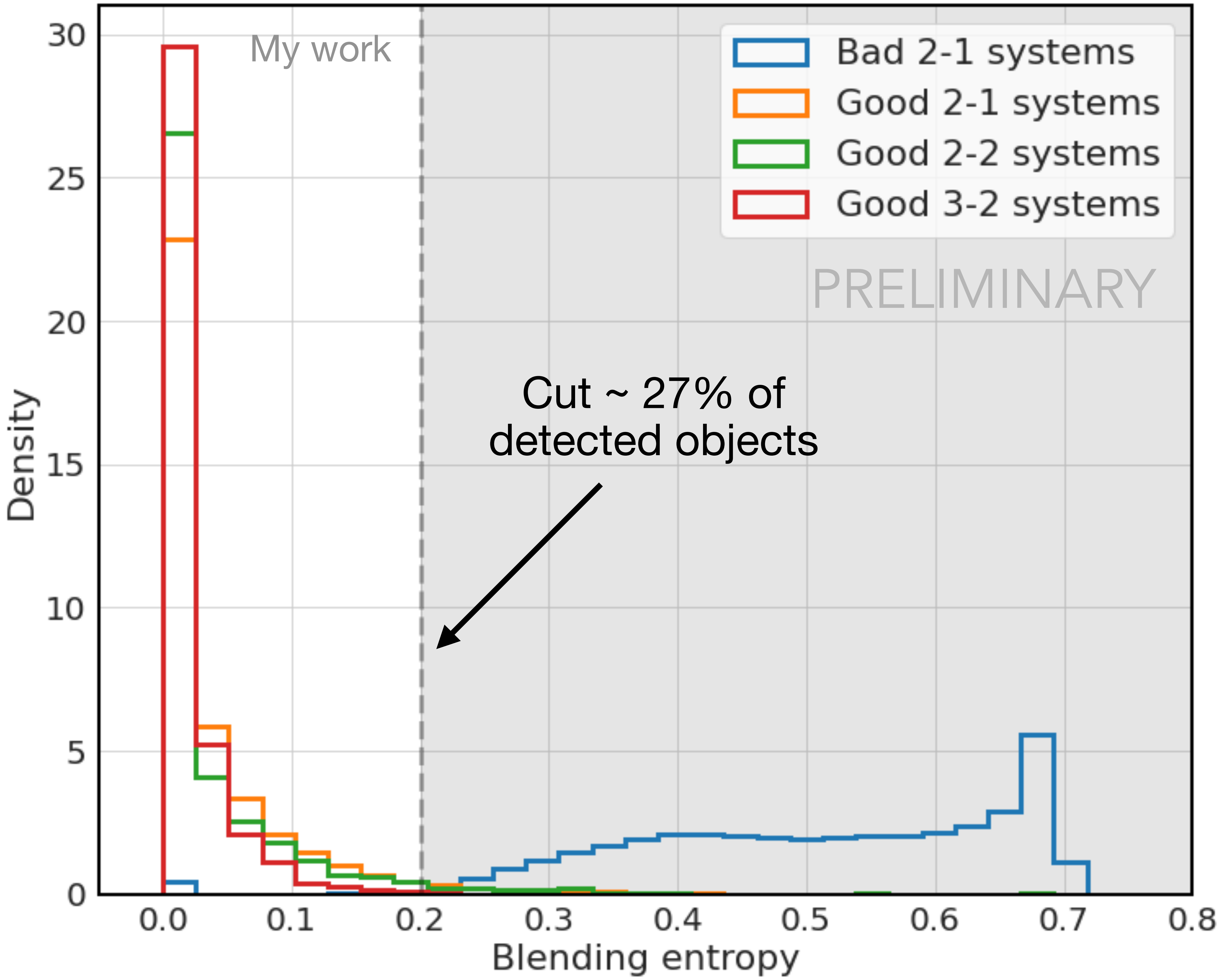
= score for each object

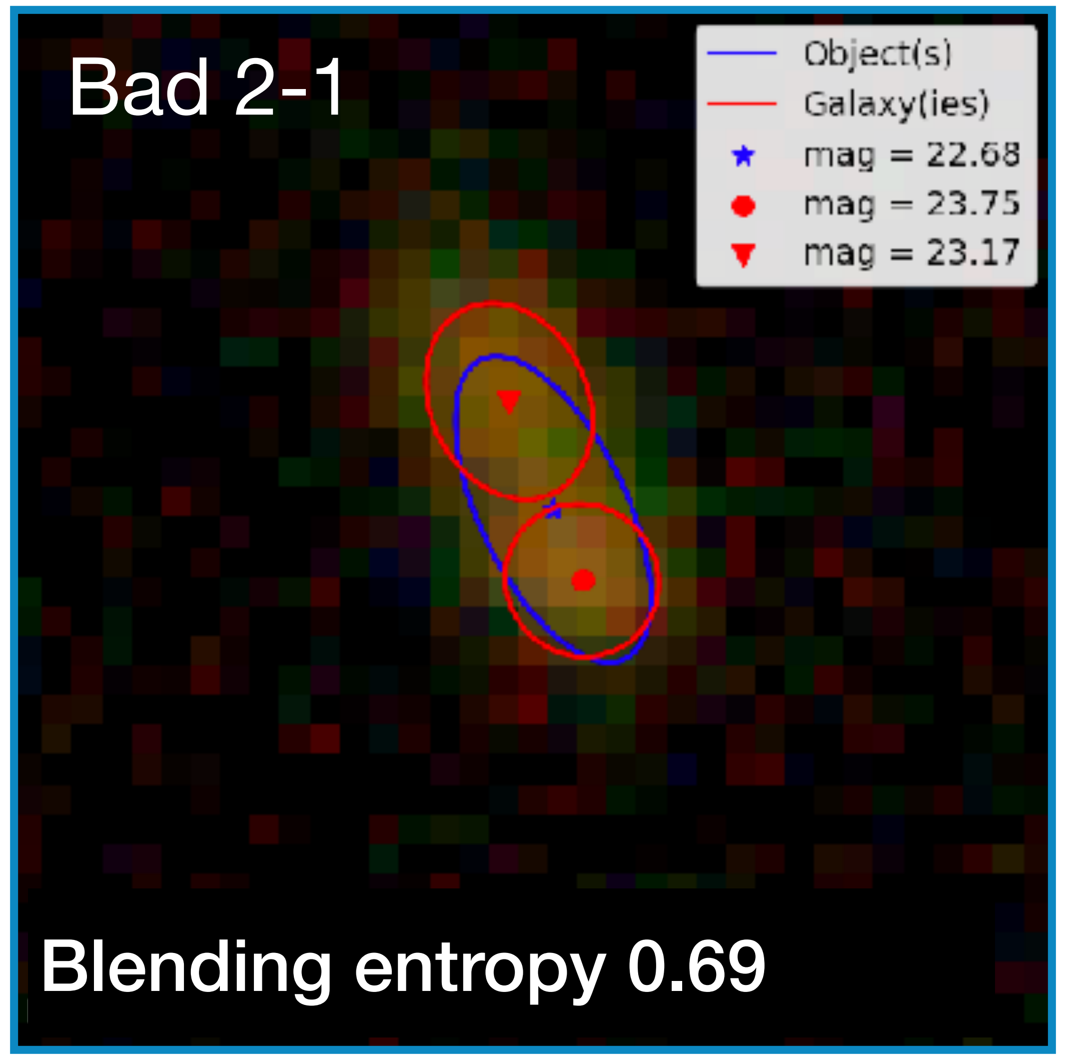
* $S_b = 0$ *for 1-1 systems*

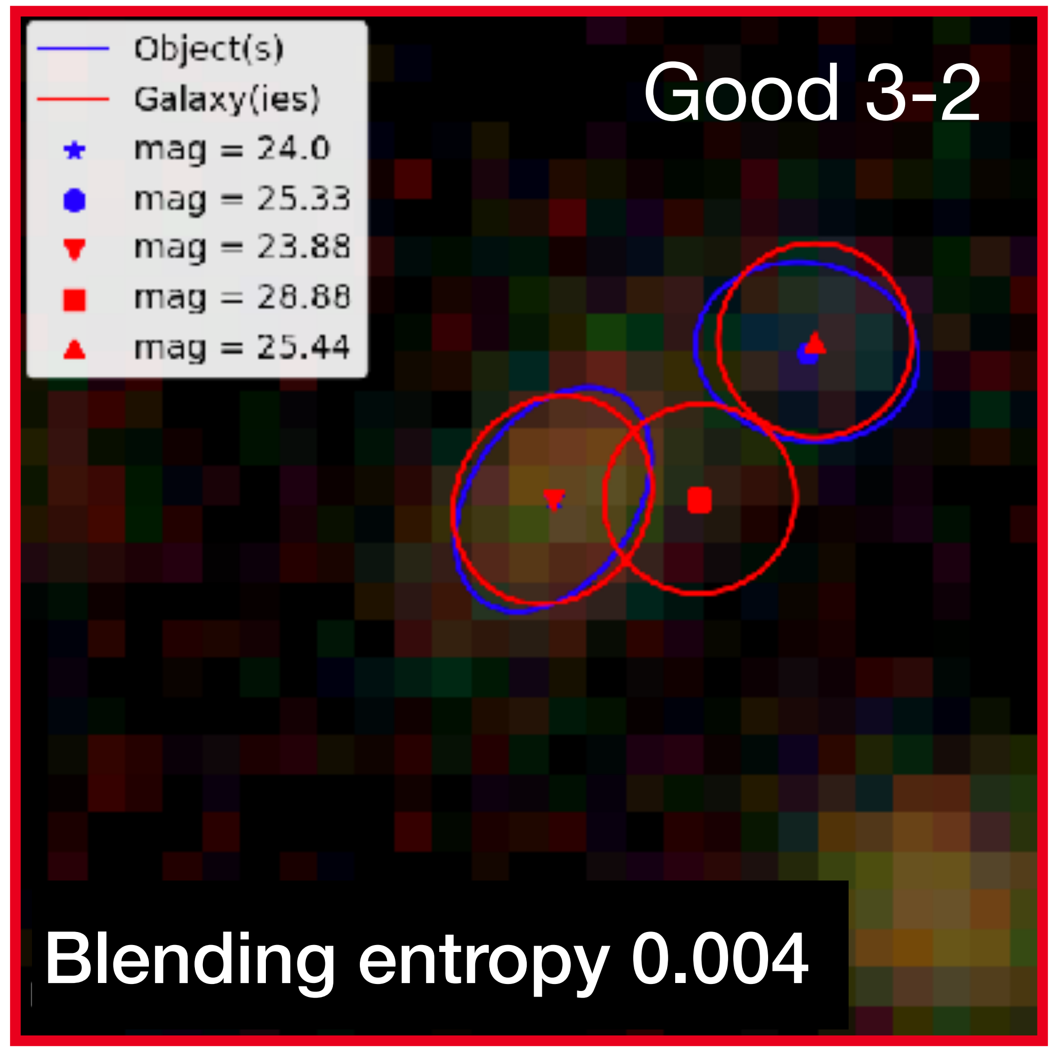
Blending entropy of blended systems









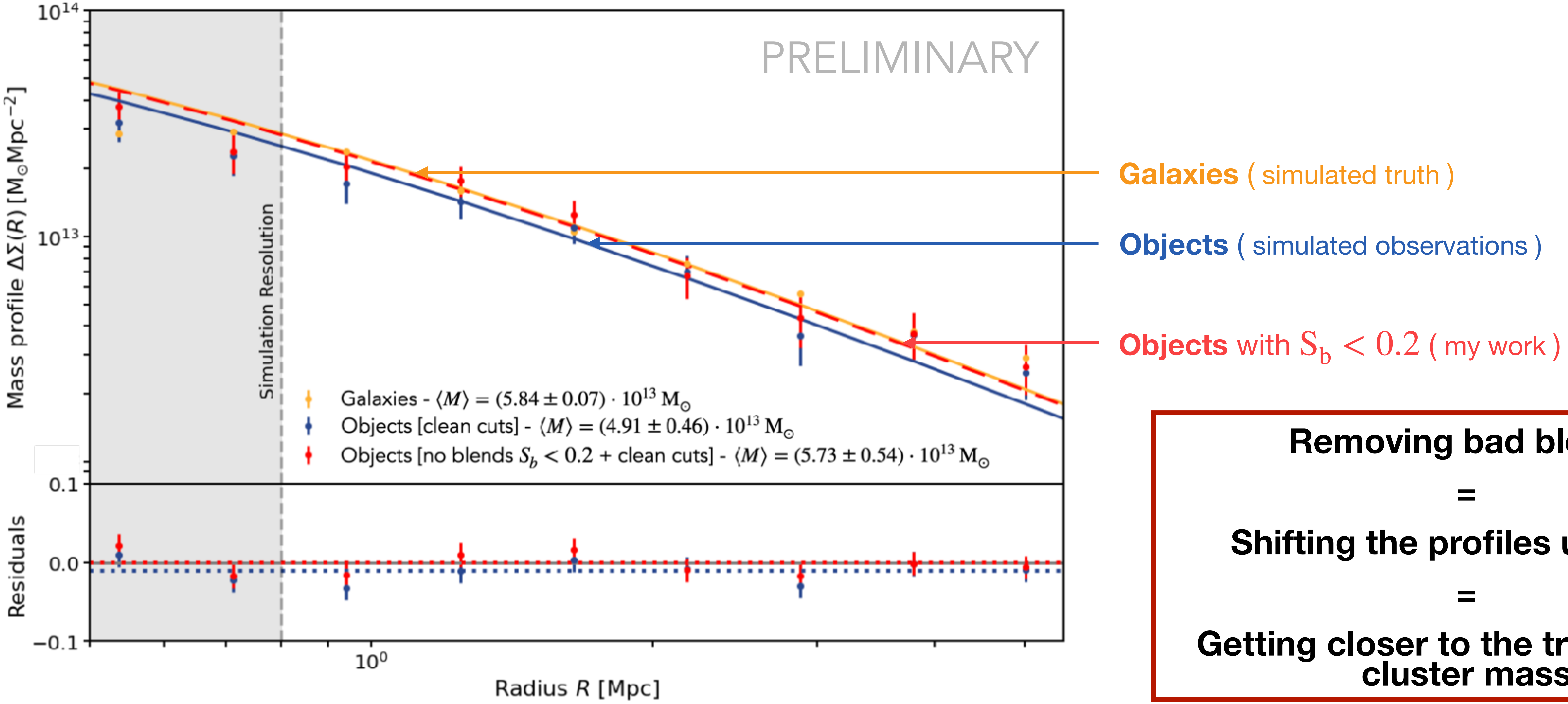


Impact of blending on weak lensing profiles

Impact of blending on $\Delta\Sigma$ profiles

DESC tool
https://github.com/LSSTDESC/CLMM

Objective: study the impact of bad blends on $\Delta\Sigma$ profiles



Removing bad blends

=

Shifting the profiles upwards

=

Getting closer to the truth galaxy cluster mass

Conclusions

1. **Development of friendly, new DESC matching algorithm**
   - Matching probabilities to characterize blending
   - Efficiency of blending entropy in separating highly vs. well-matched systems

2. **Impact of blending on cluster lensing profiles**
   - Profiles biased low due to blending
   - Partly recovered by removing identified blends

3. **Need to propagate this study to cosmological parameters**

Thank you for your attention!