Probabilistic characterization of blending in Rubin/LSST: application to cluster lensing cosmology

LSST France, June 2025

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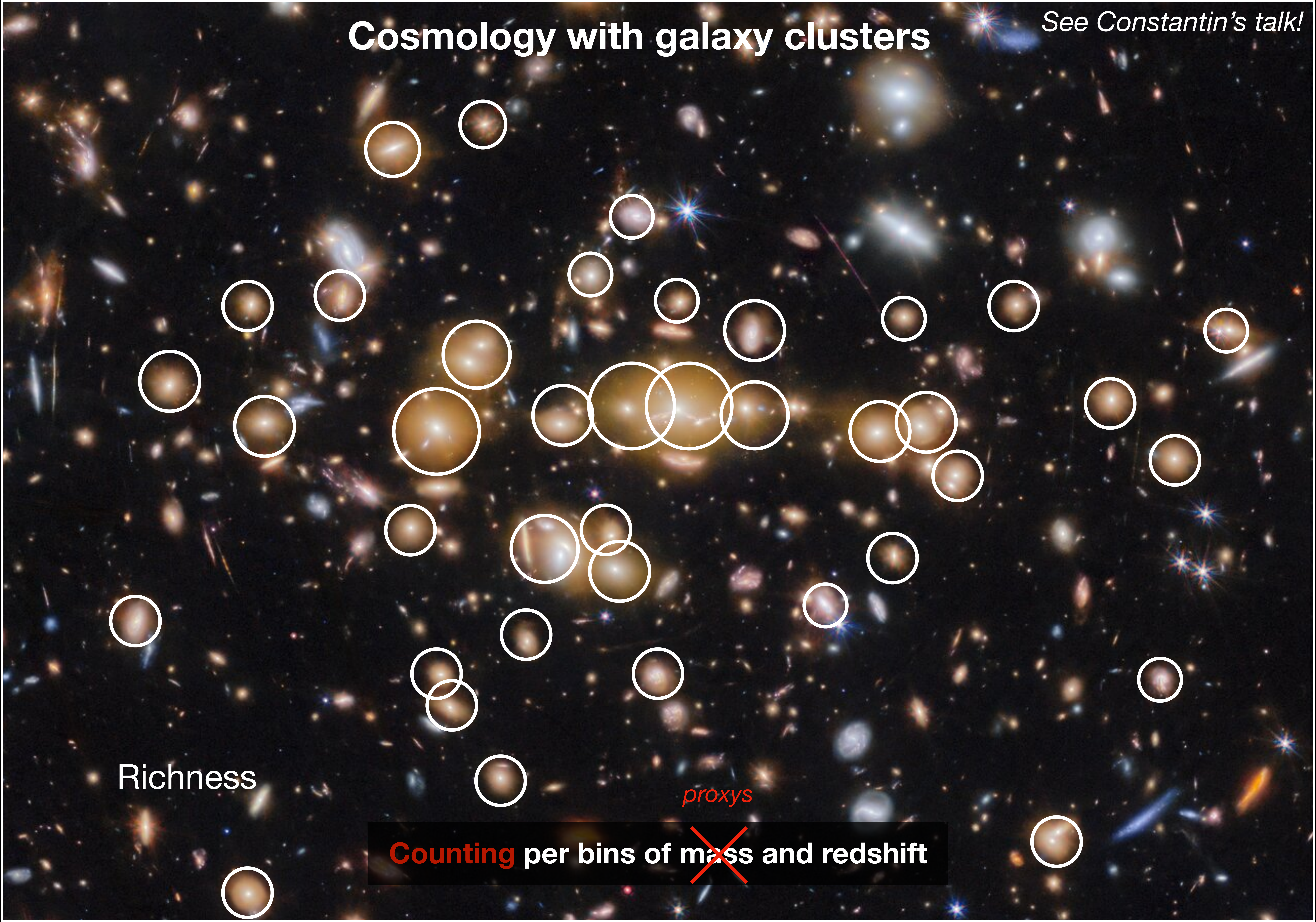
GRENOBLE | MODANE

Legacy Survey of Space and Time

Dark Energy Science Collaboration

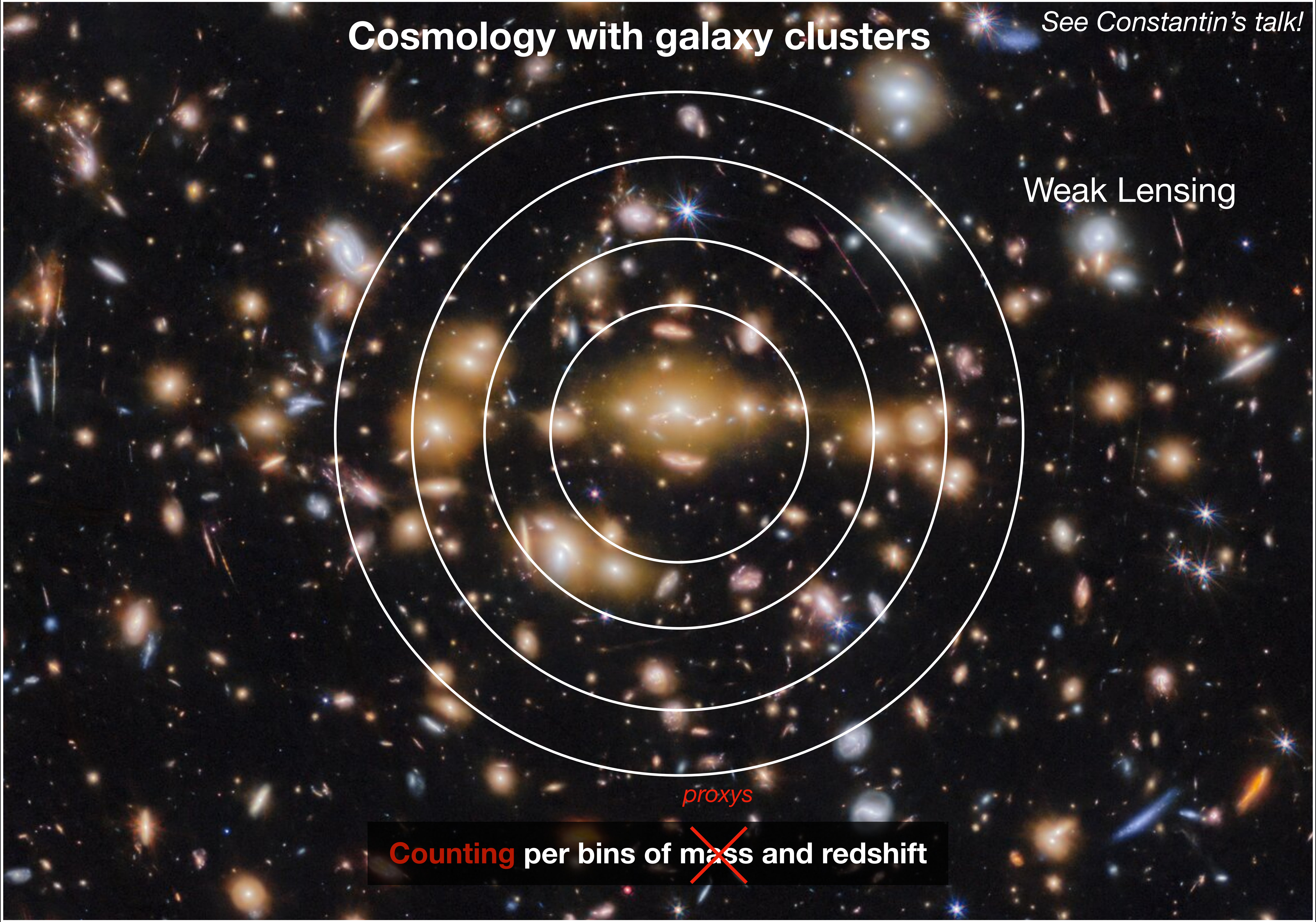
Cosmology with galaxy clusters

See Constantin's talk!



Cosmology with galaxy clusters

See Constantin's talk!



Weak Lensing

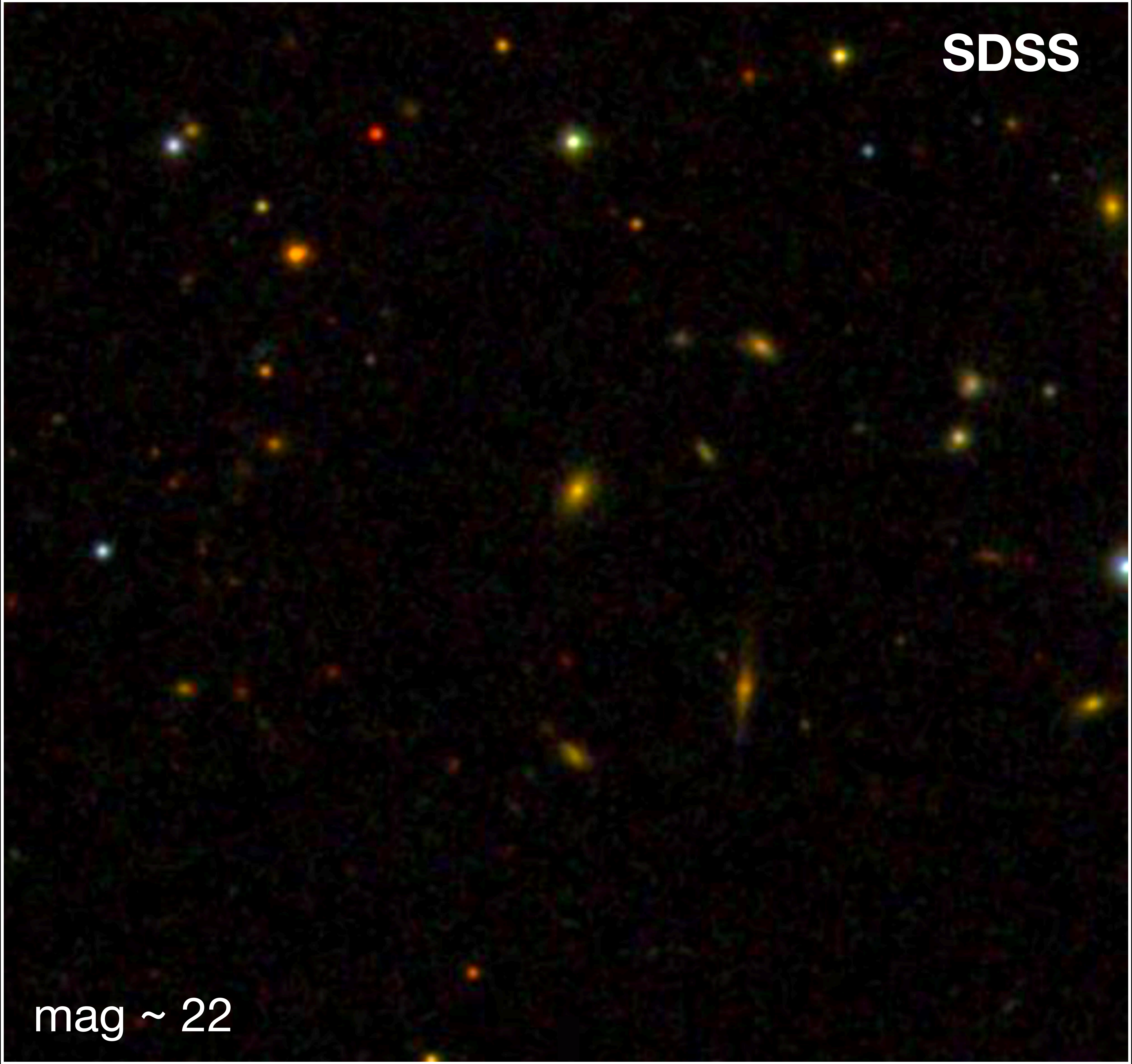
proxys

Counting per bins of ~~mass~~ and redshift

Blending

Superposition of galaxies due to:

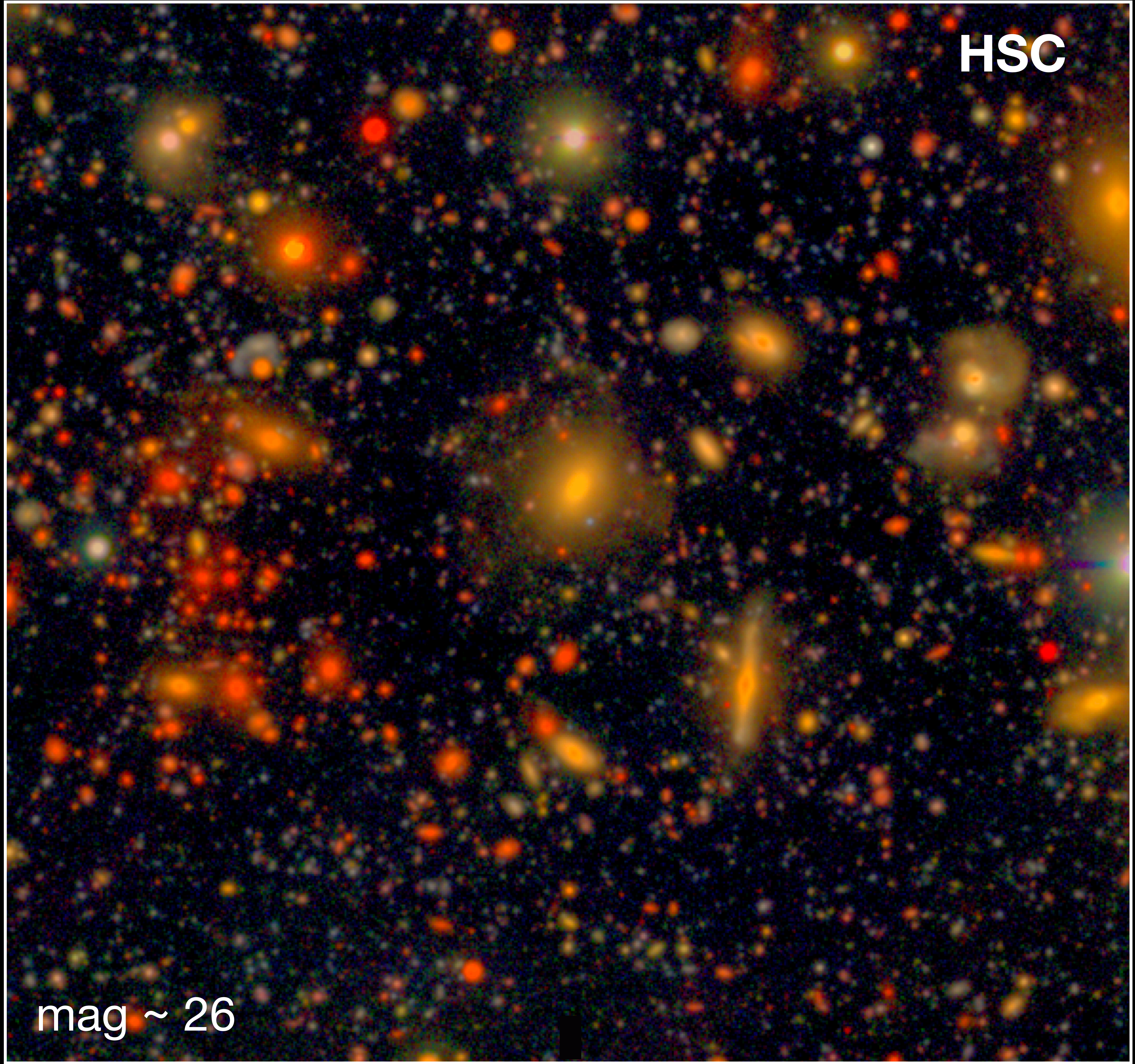
- The depth of observation
- The PSF size



Blending

Superposition of galaxies due to:

- The depth of observation
- The **PSF size**



Blending

Superposition of galaxies due to:

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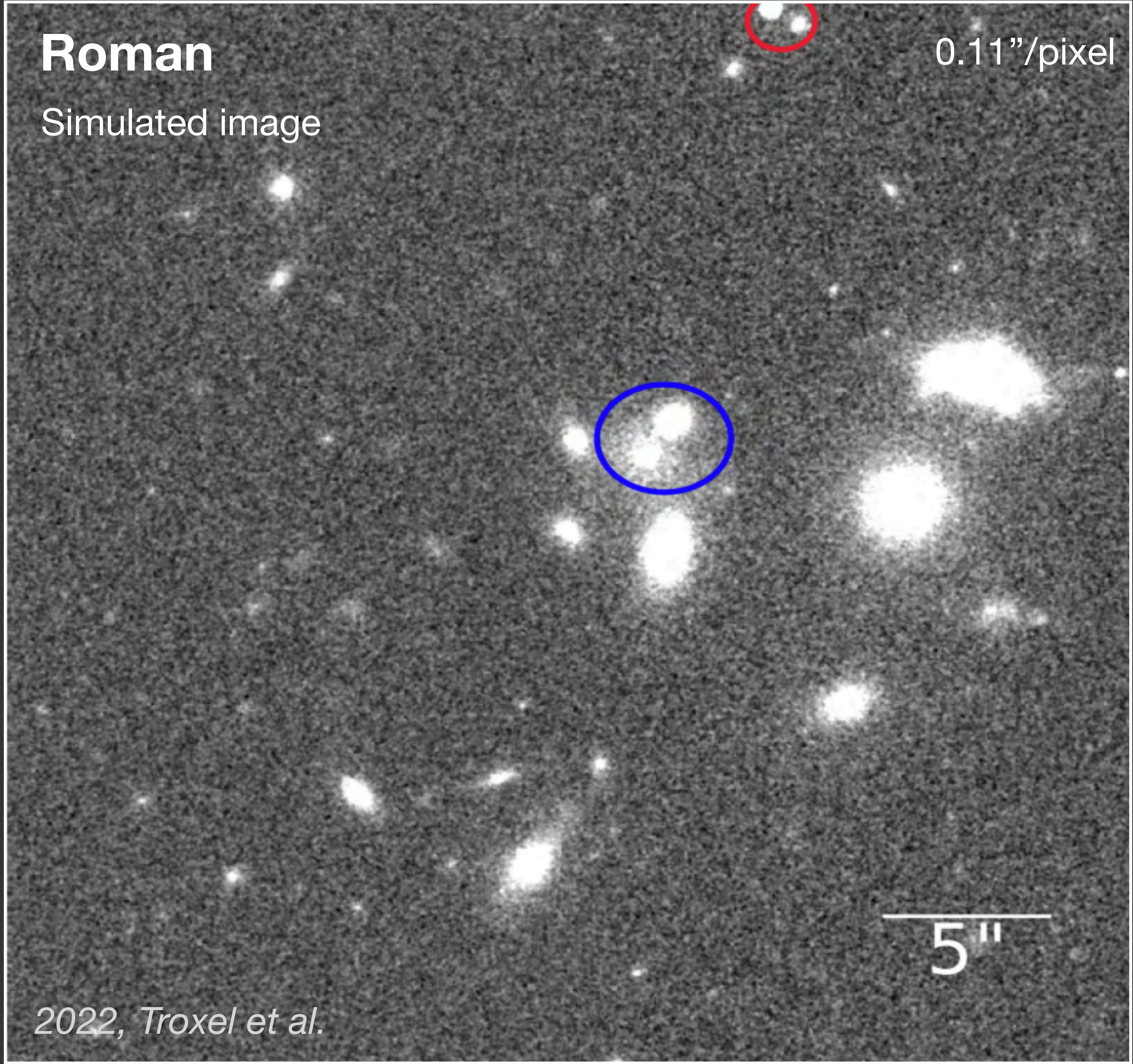

Blending

Superposition of galaxies due to:

- The **depth** of observation
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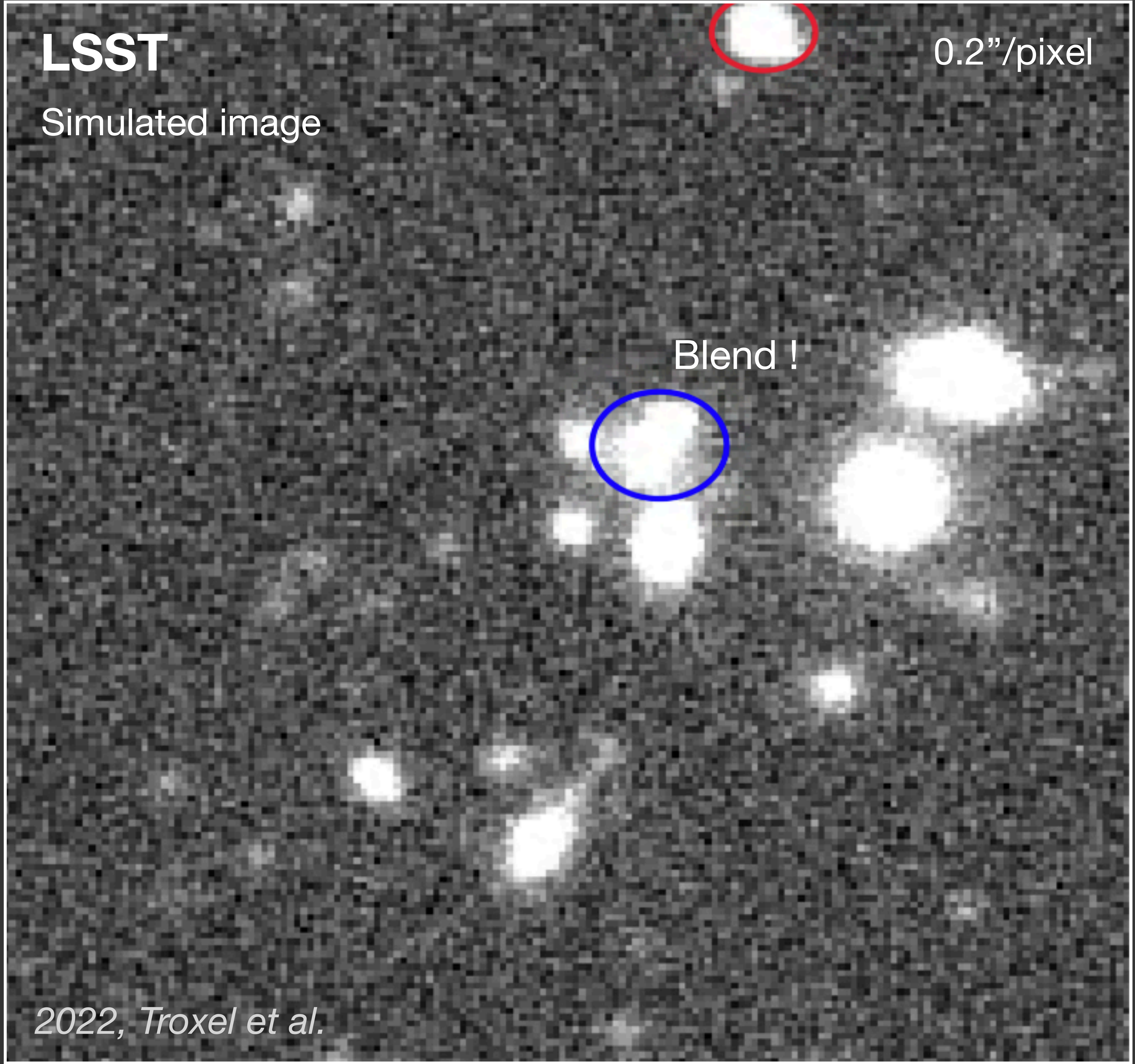
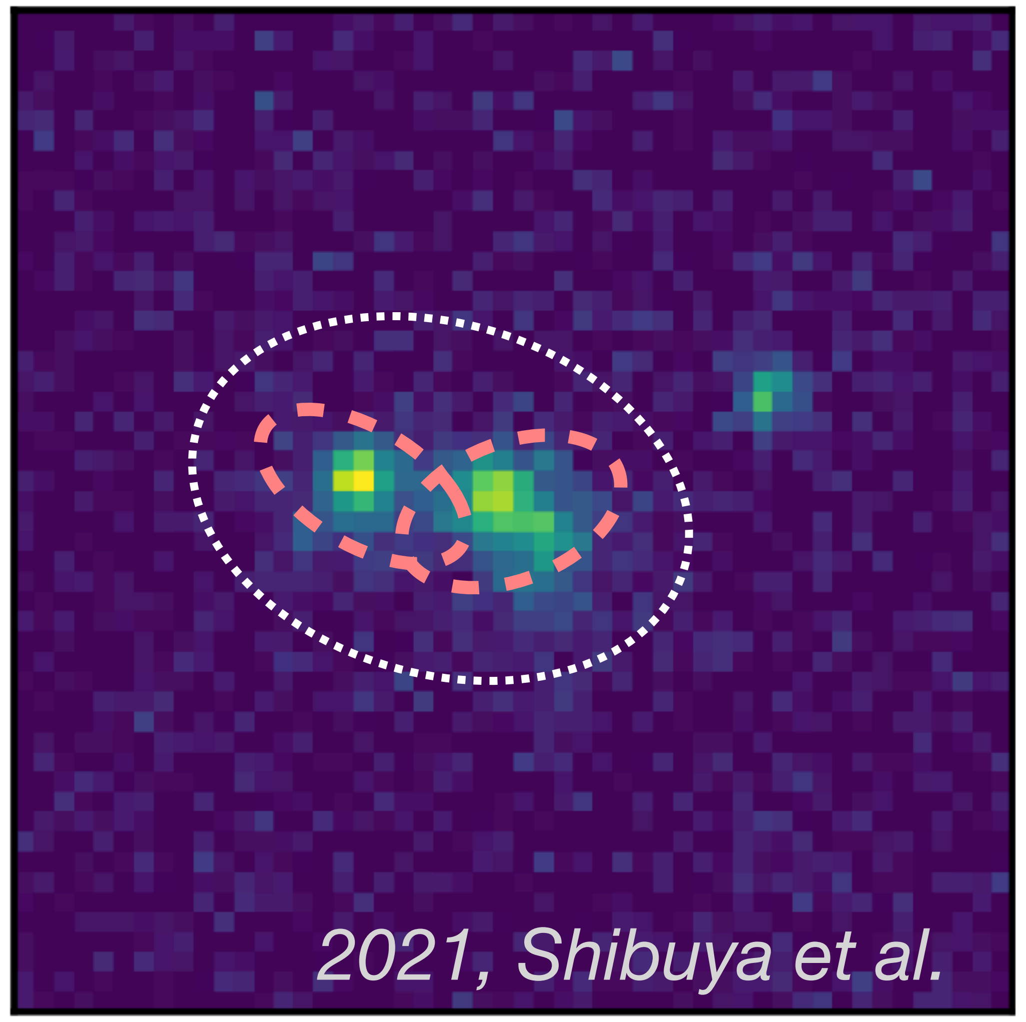


Recognized/unrecognized blends

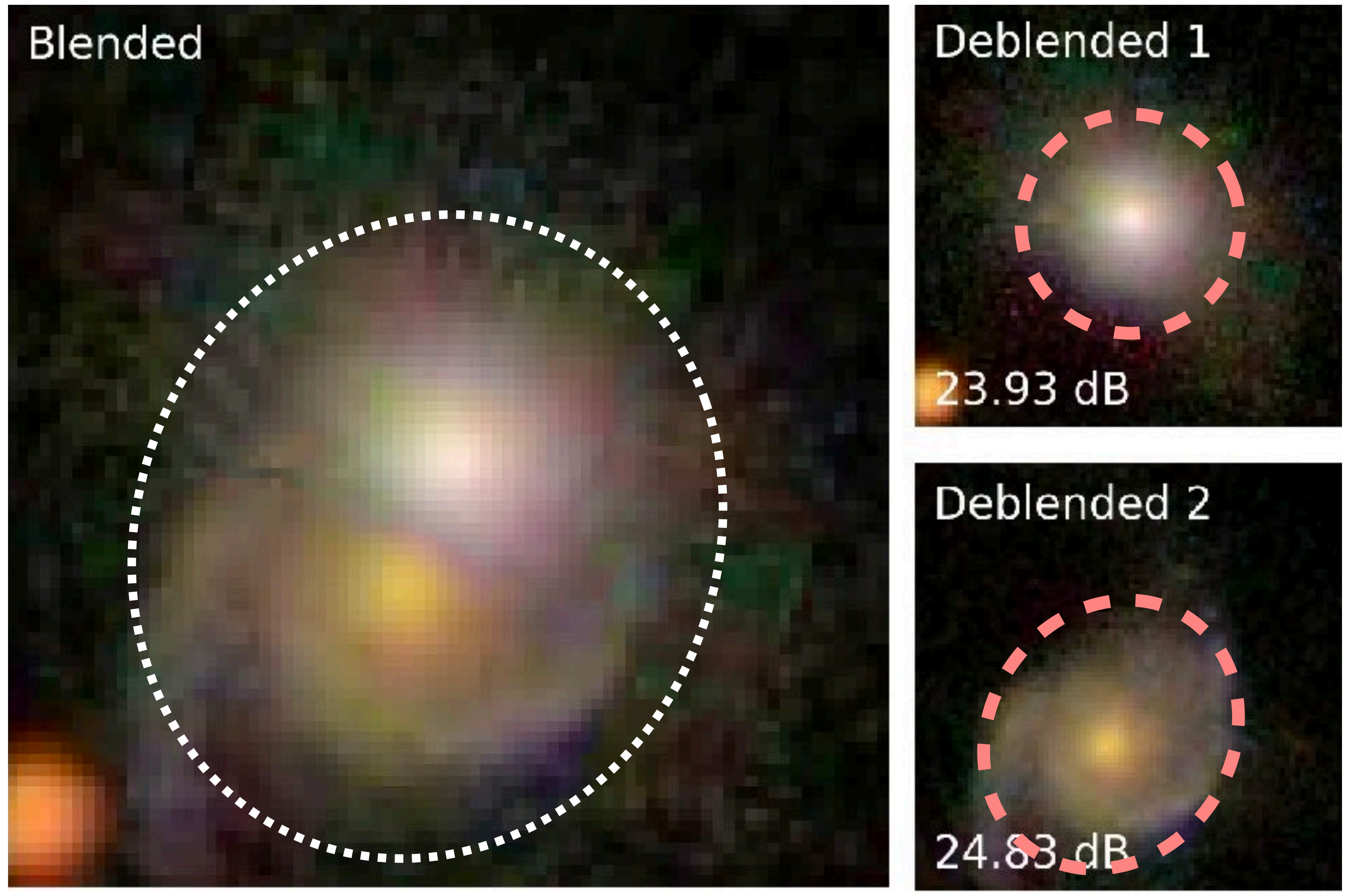
* 2016, Dawson et al.
2022, Troxel et al.

Recognized blends

Hubble/ACS



LSST deblender: **SCARLET****



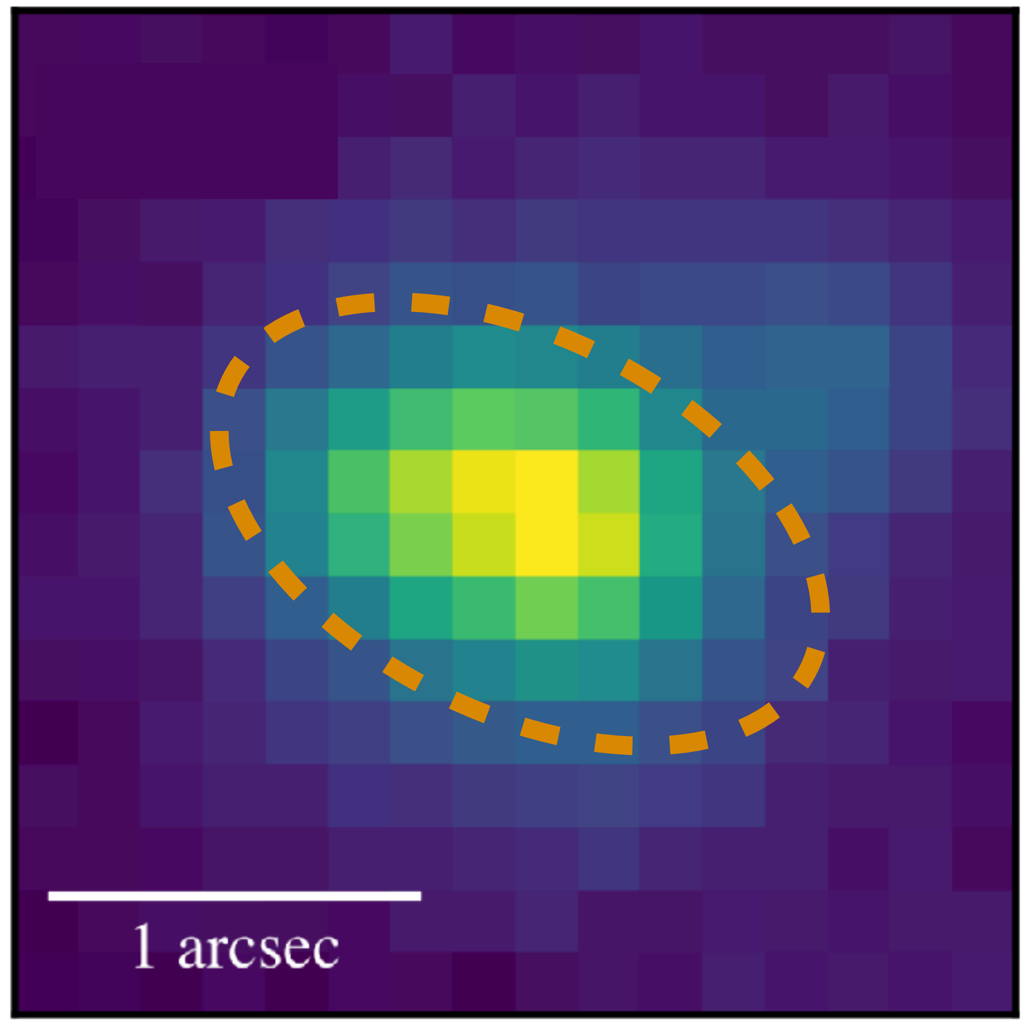
~40 %

~ 60% of blends

- Detection
- Shapes
- Redshifts

Unrecognized blends

Subaru/HSC

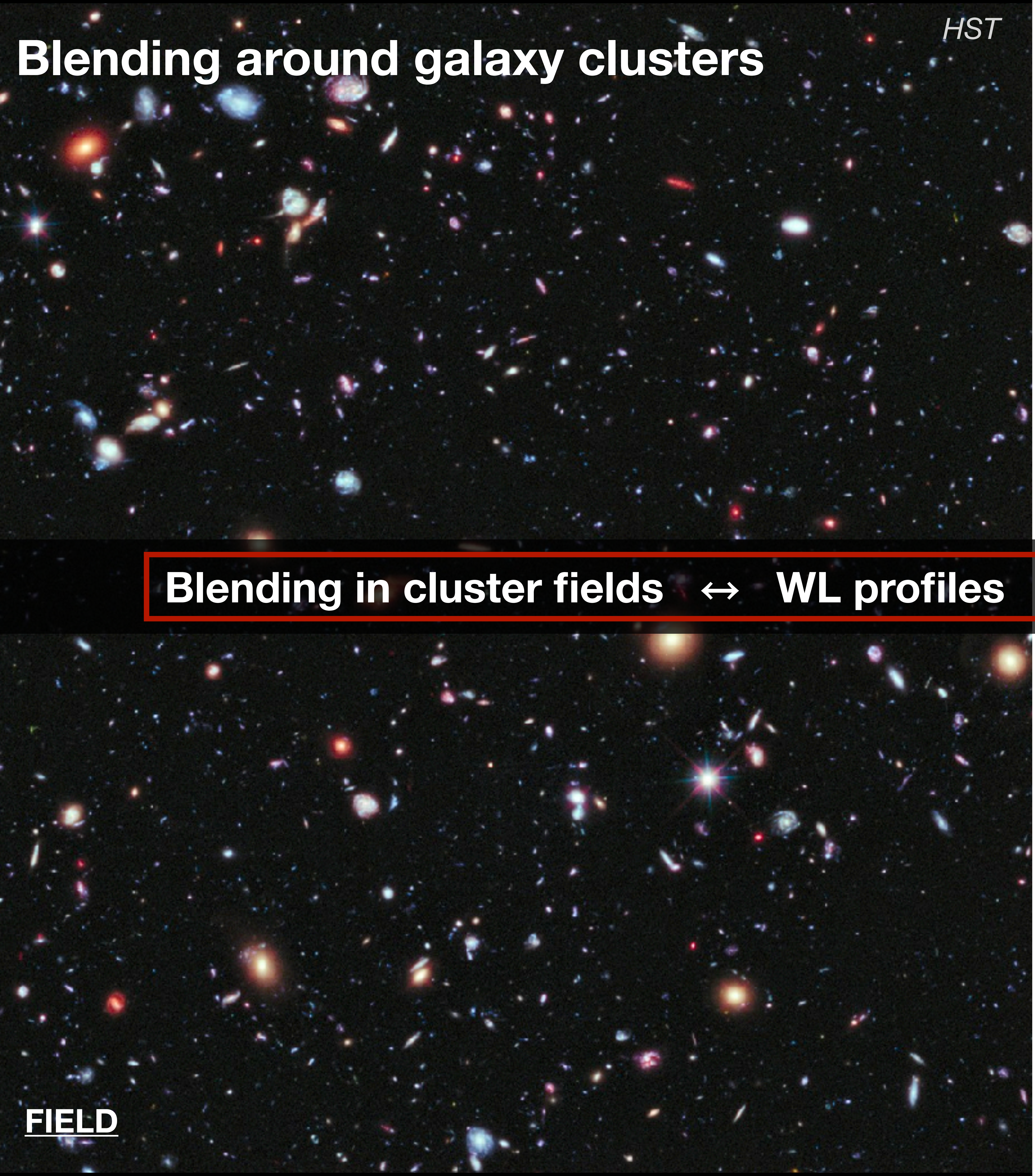


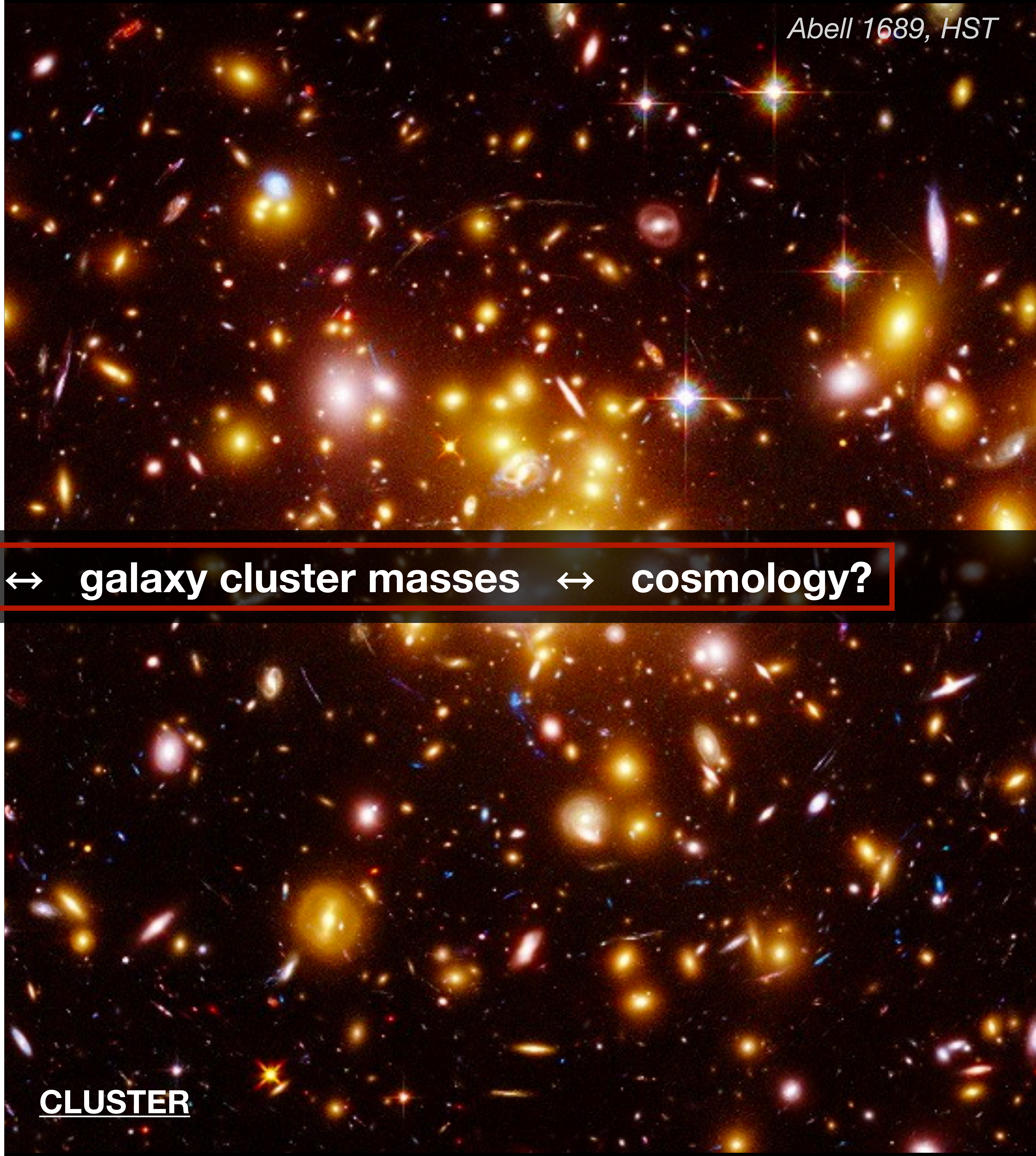
?

~14 - 20 %*

** 2018, Melchior et al.

Blending around galaxy clusters



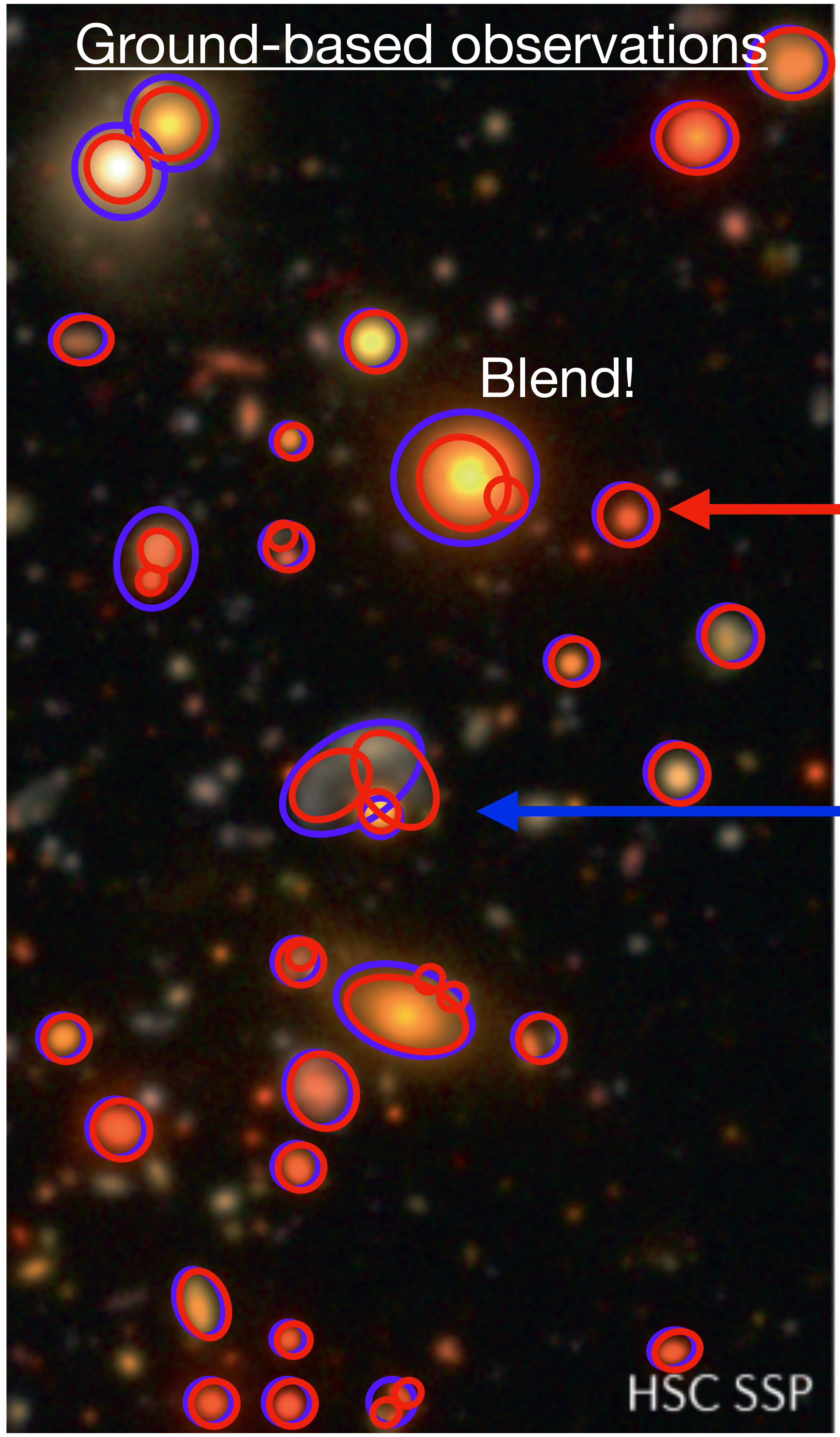


Blending in cluster fields ↔ WL profiles ↔ galaxy cluster masses ↔ cosmology?

Identification of blends in LSST

Detection of unrecognized blends

Detection of unrecognized blends

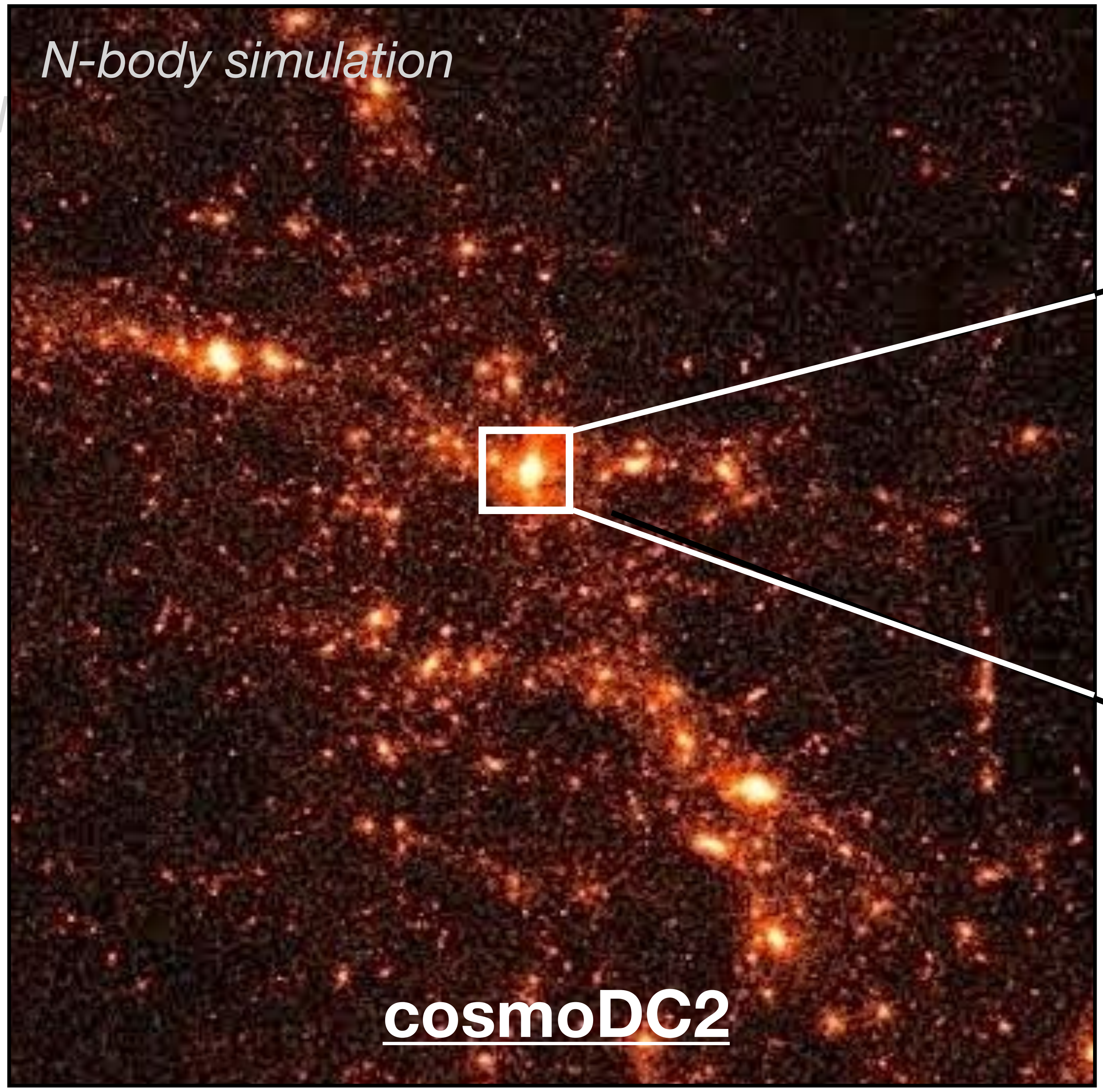


Simulated data

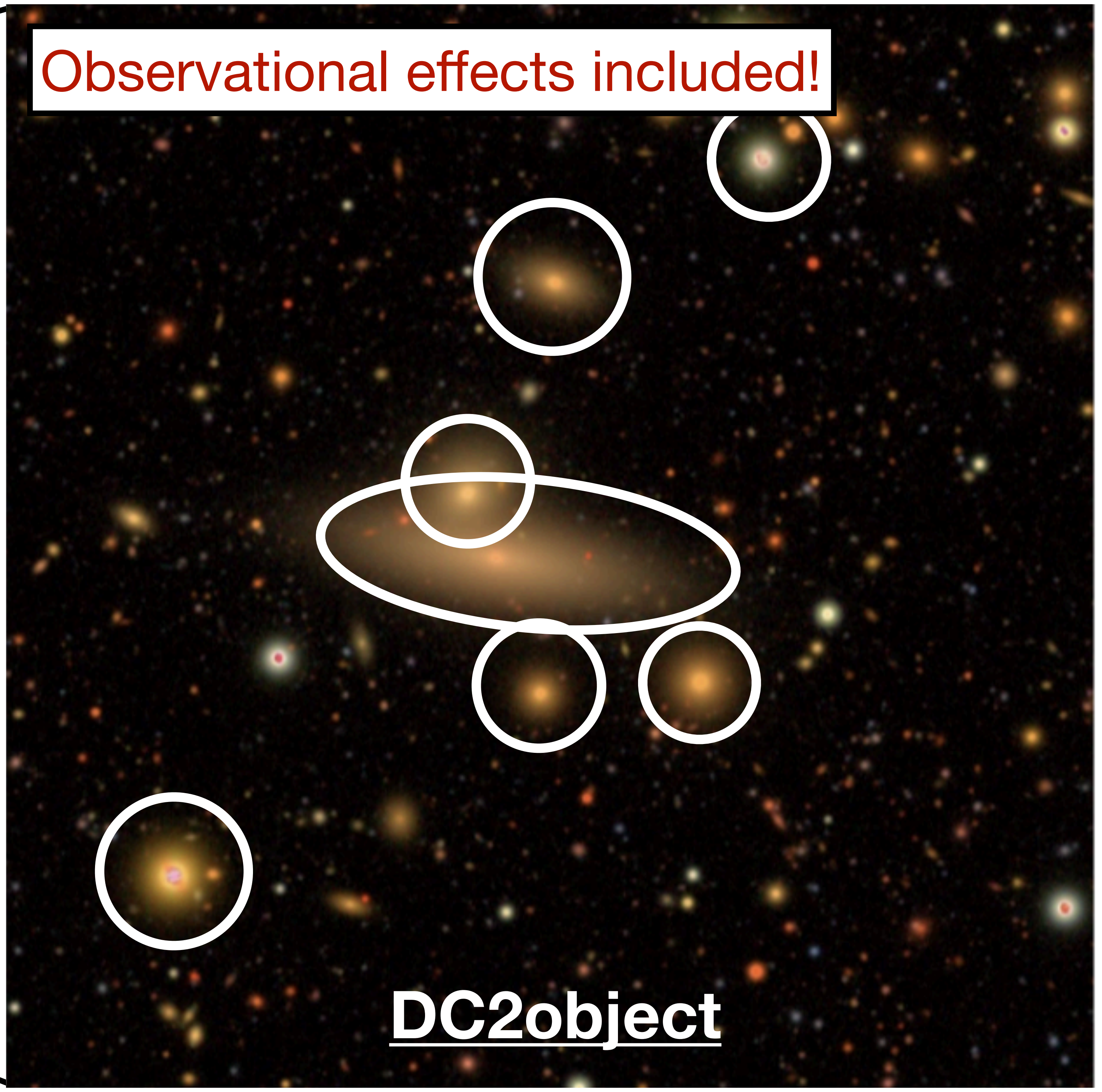
Truth galaxy

Detected object

Simulated catalogs



Outer Rim 2019, Heitmann et al.



DESC simulated image

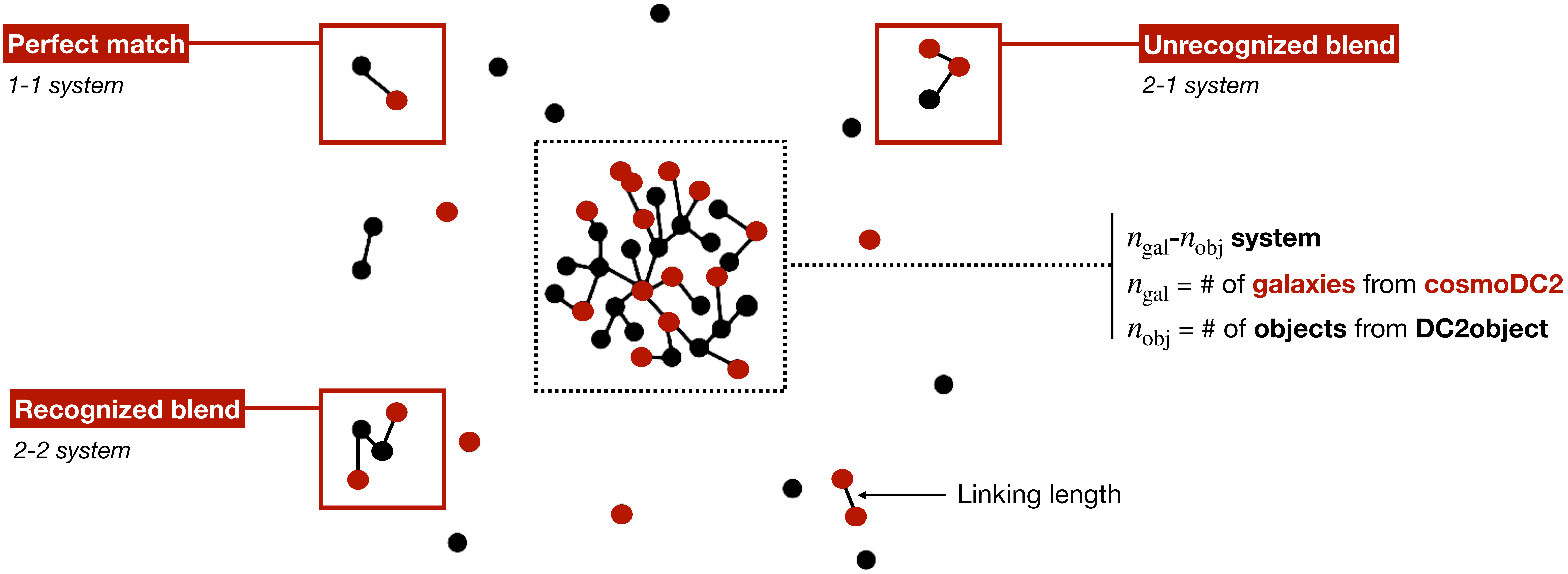
Reference for **galaxies** and dark matter haloes

Detected **objects** from realistic simulated images

Identification of blends through catalog matching

First attempt of matching

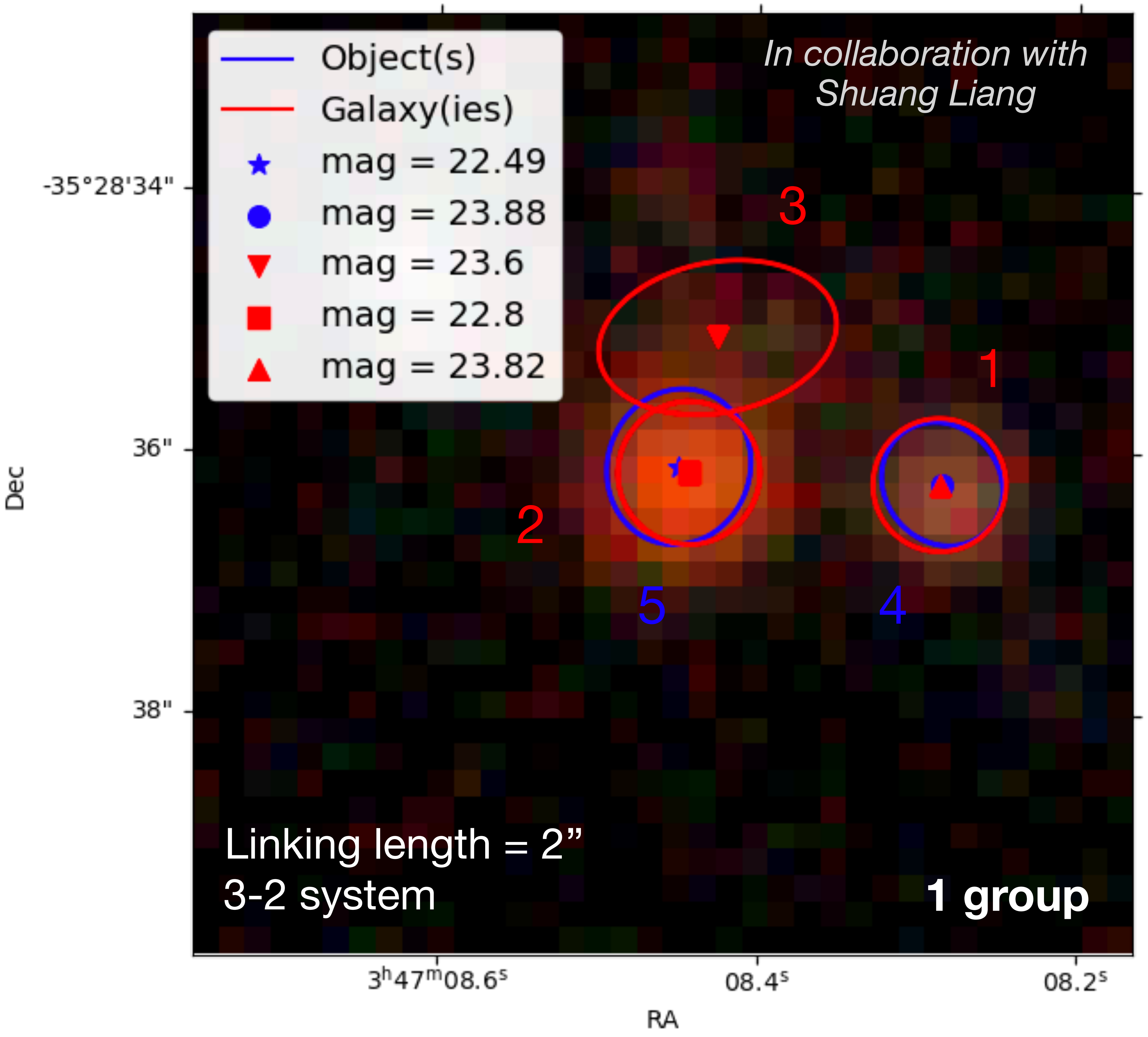
https://github.com/yymao/FoFCatalogMatching

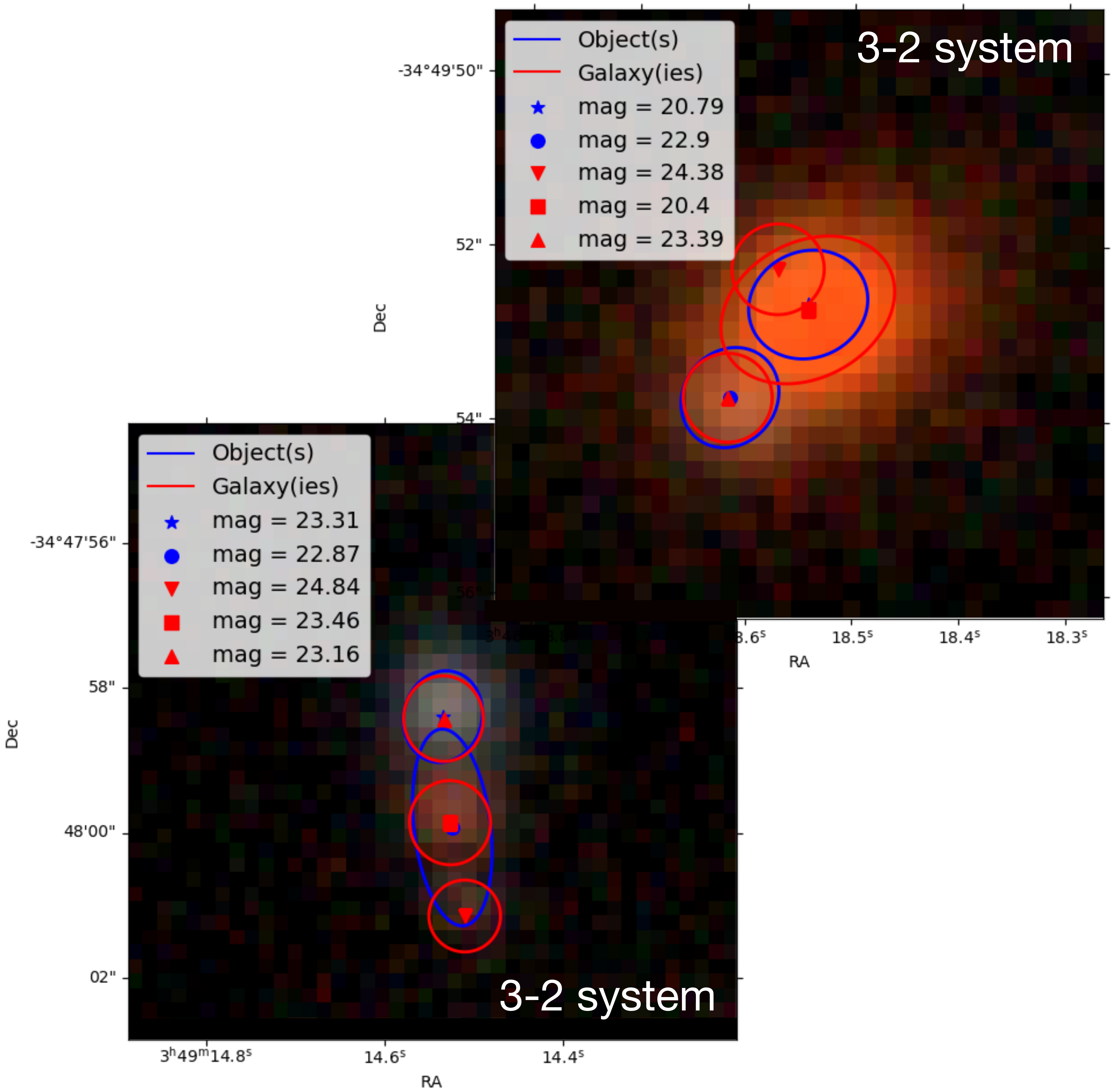


Identification of blends in LSST

Look at FoF groups

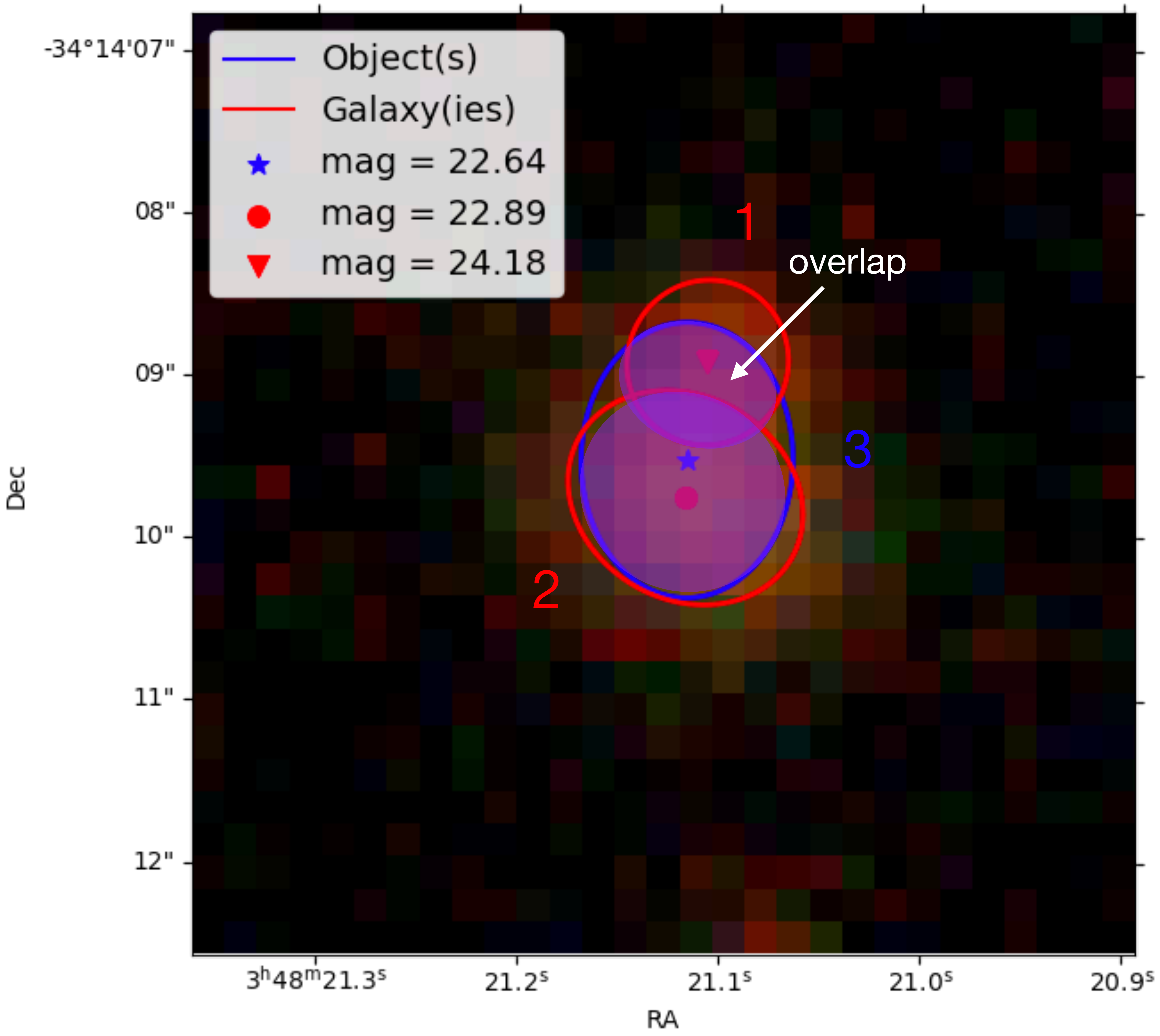
https://github.com/LSSTDESC/friendly/tree/FoF
https://github.com/LSSTDESC/Cluster_Blending





Need to account for position + shape + flux information

Blending as a matching ambiguity



Object-Galaxy matching probability

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

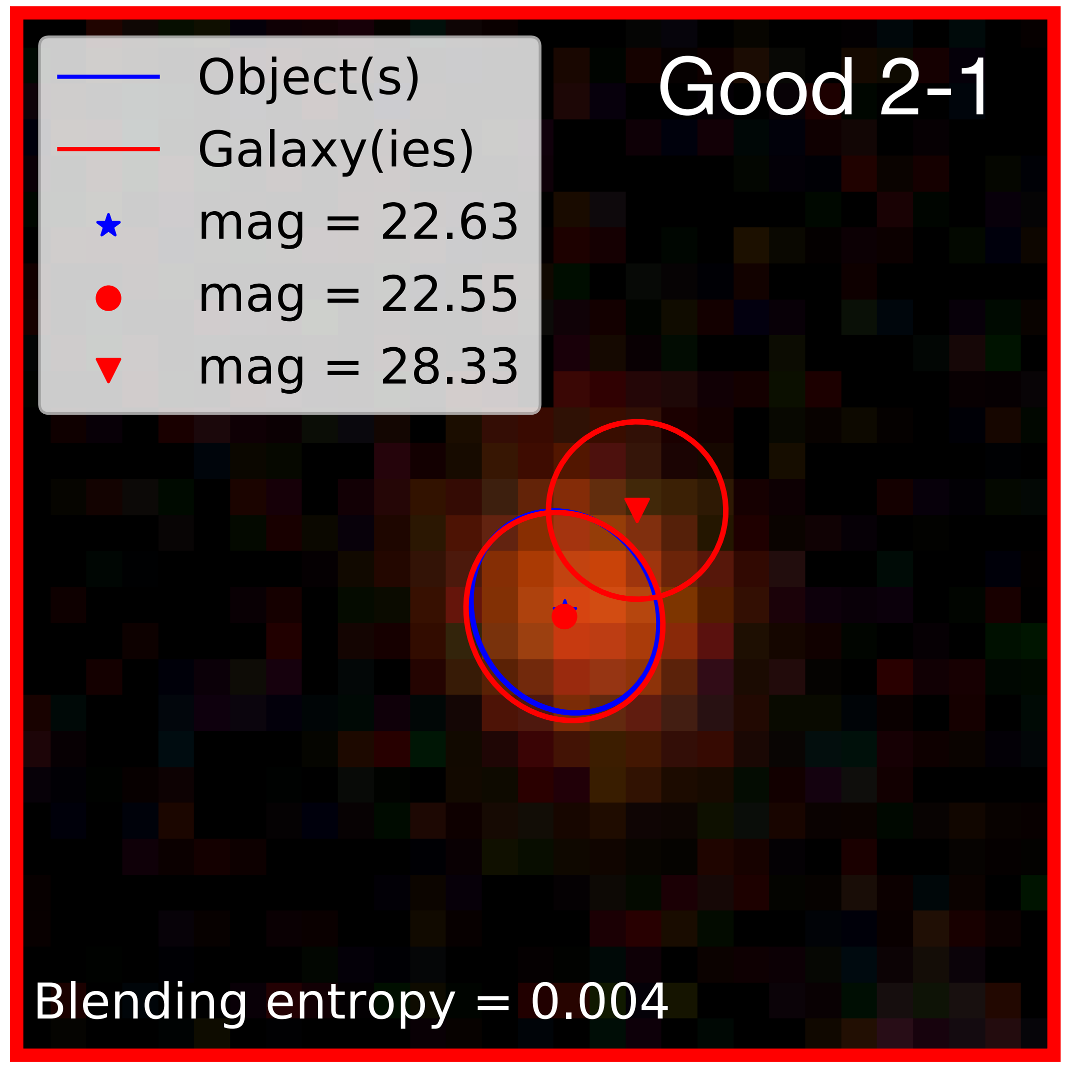
Blending entropy

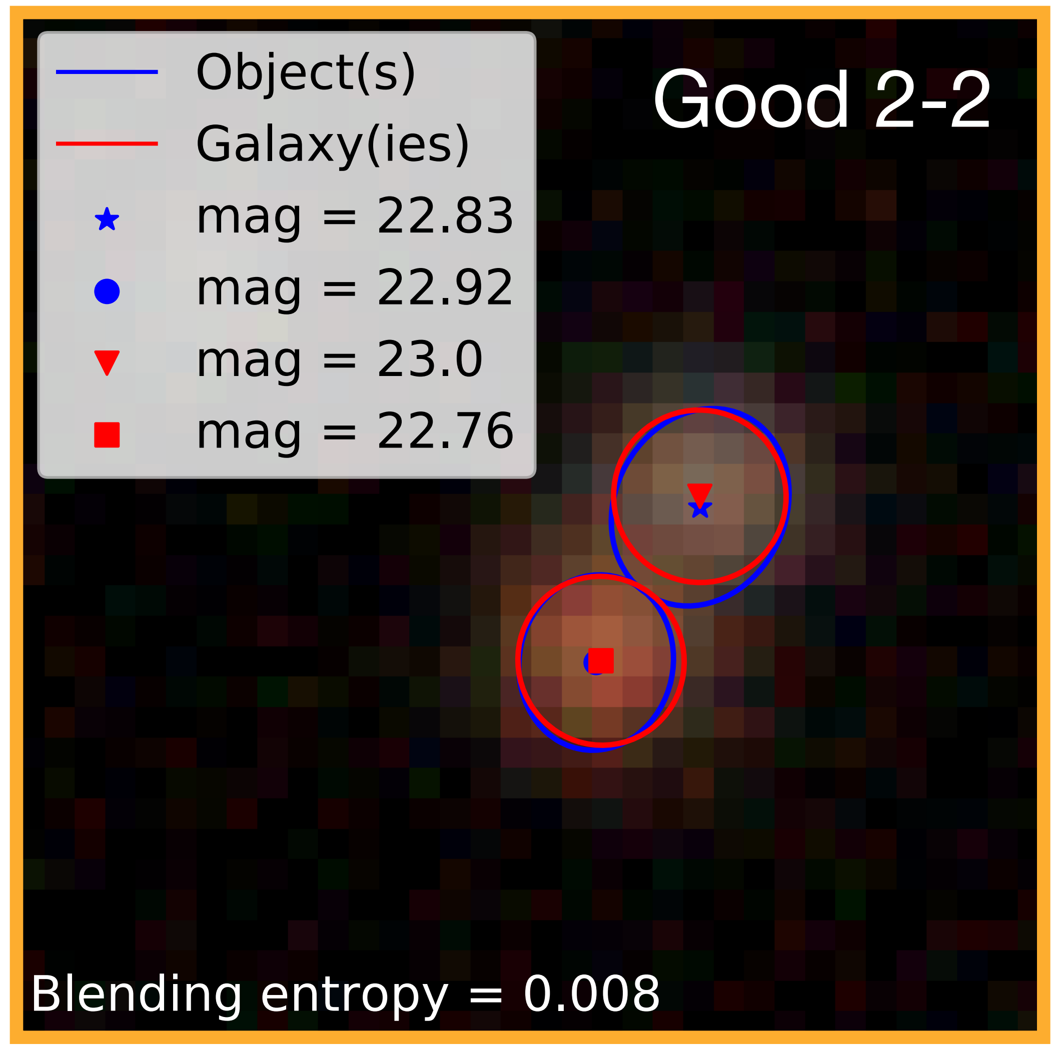
$$\boxed{S_b = -\sum_{i \in gal} p_i \log p_i}$$

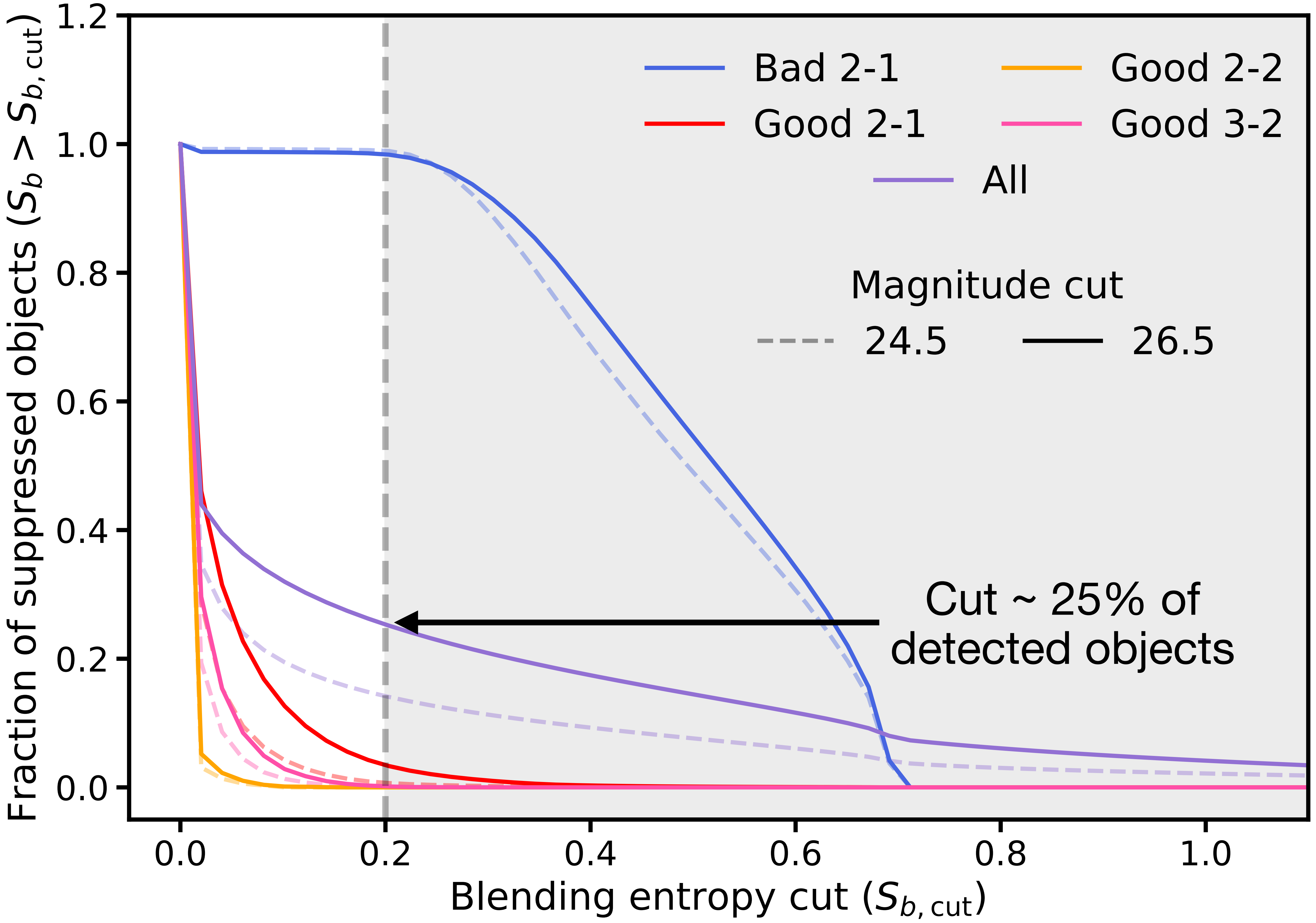
= score for each object

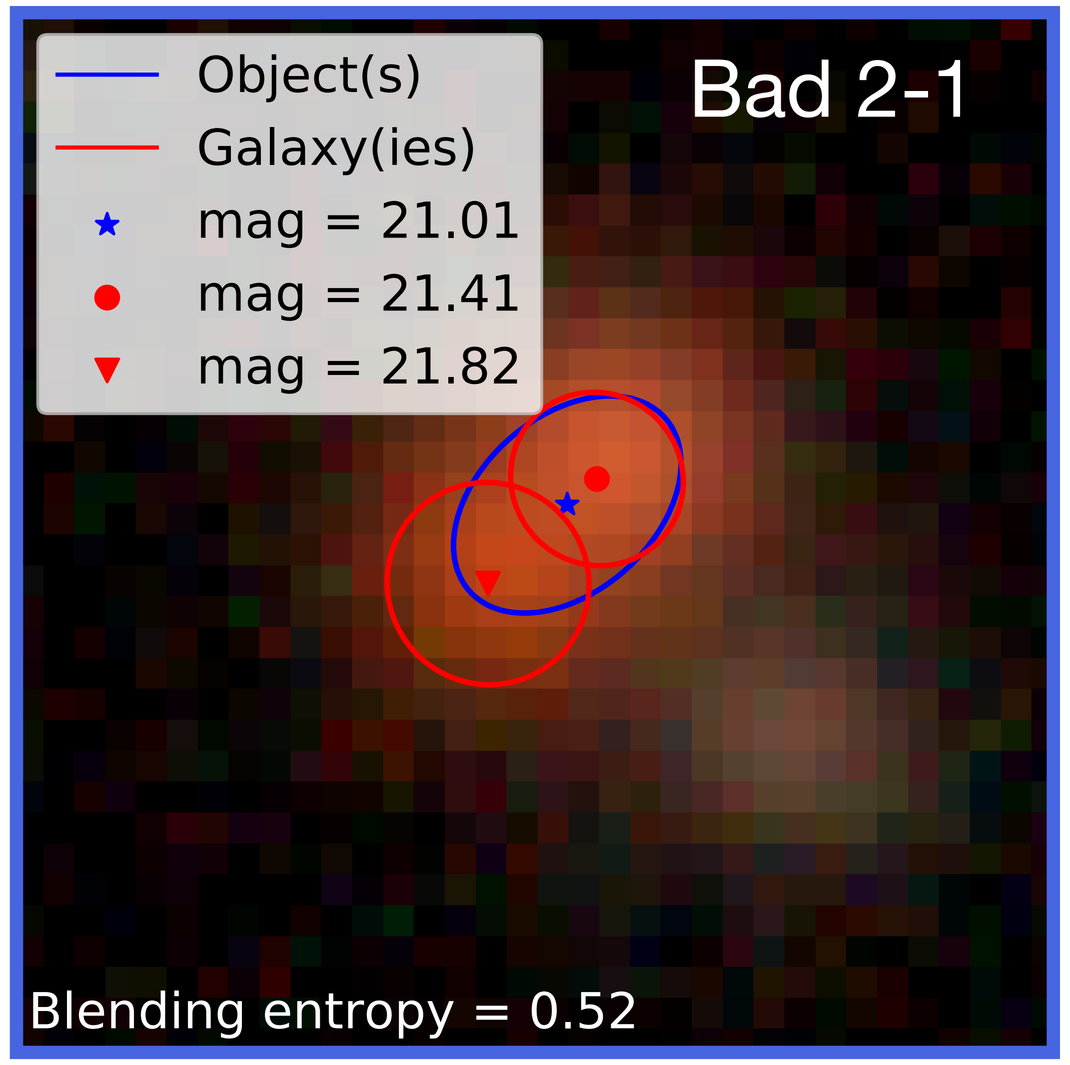
* $S_b = 0$ *for 1-1 systems*

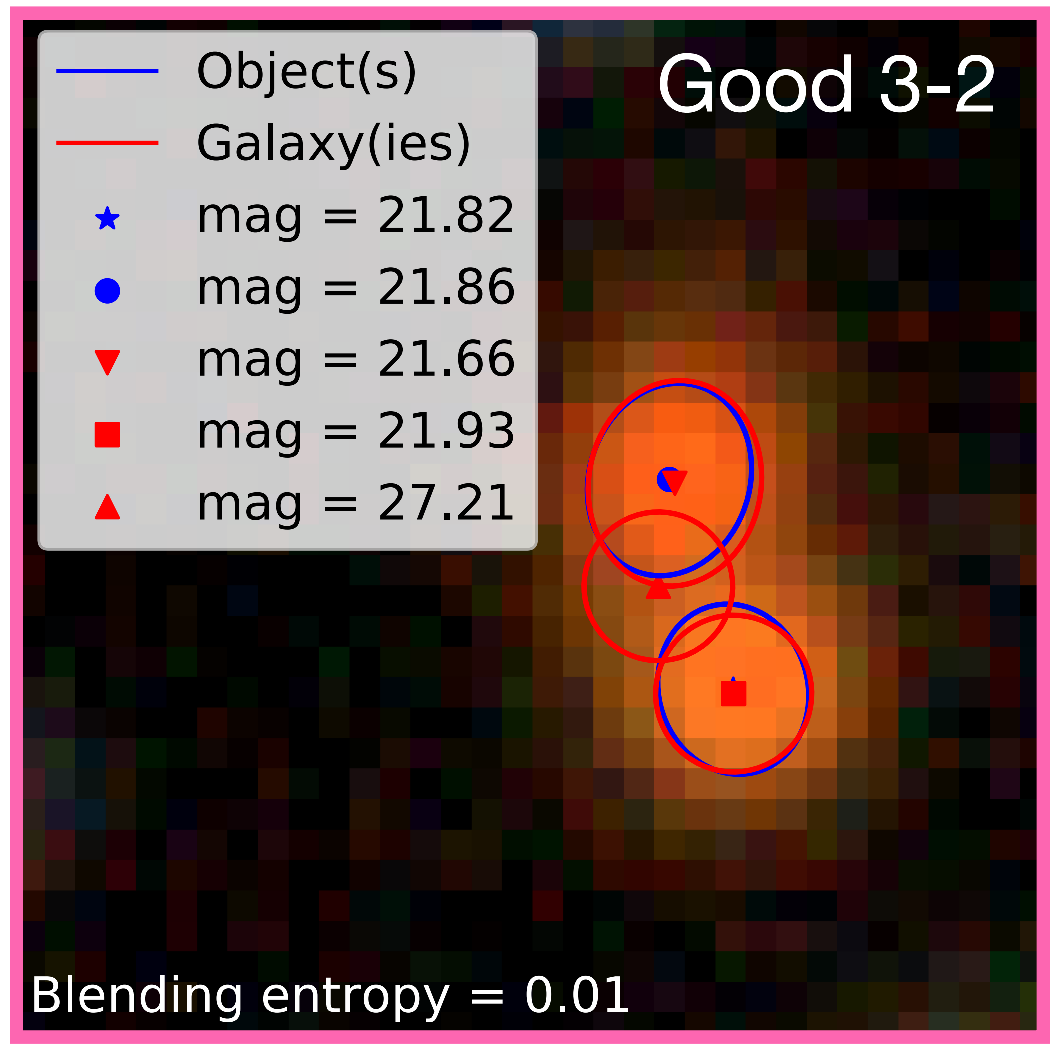
S_b as discriminant of blended systems



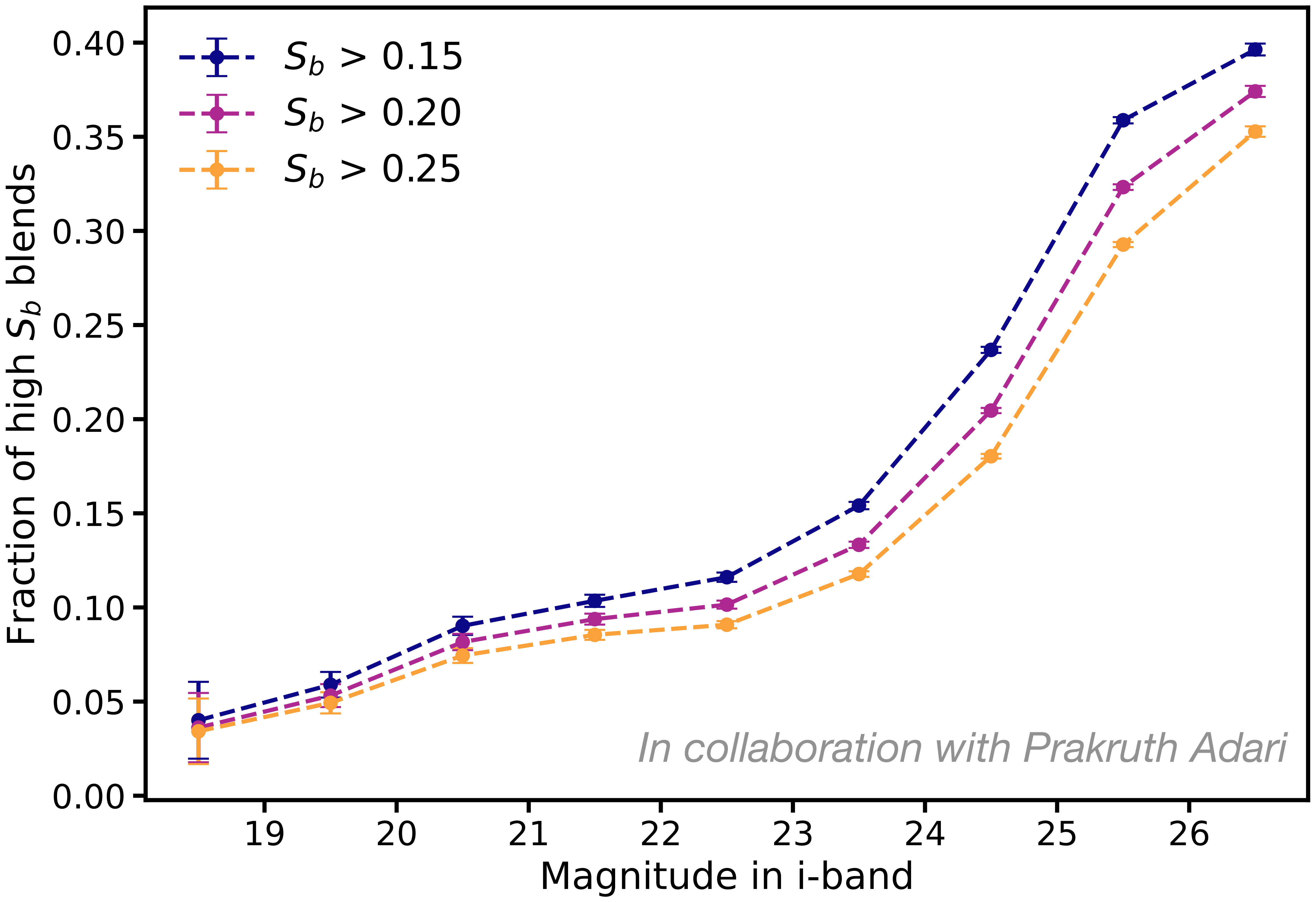








Blending entropy and magnitude



Fraction of high S_b blended objects increases with magnitude

Blending entropy and blendedness

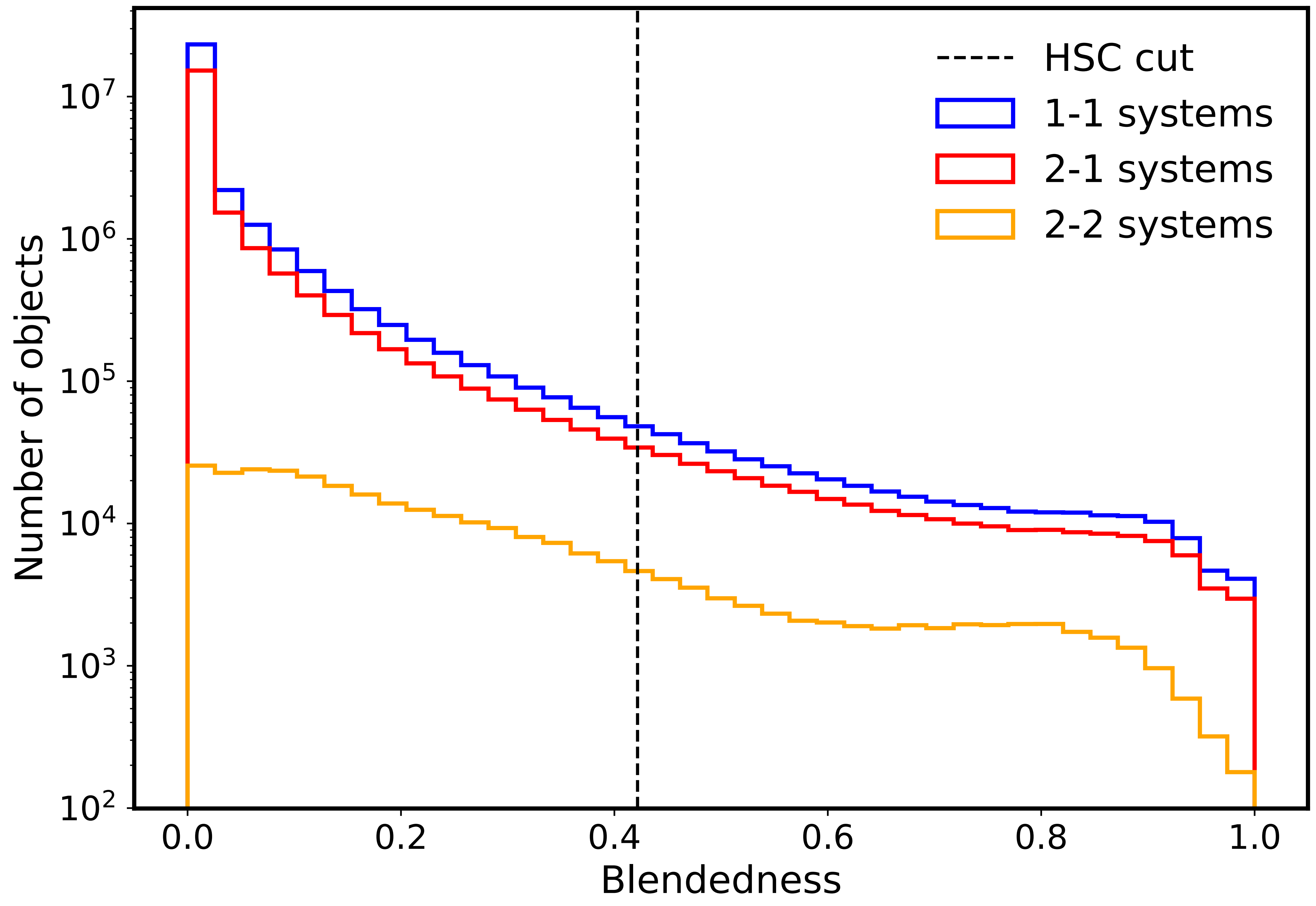
2018, Mandelbaum et al.

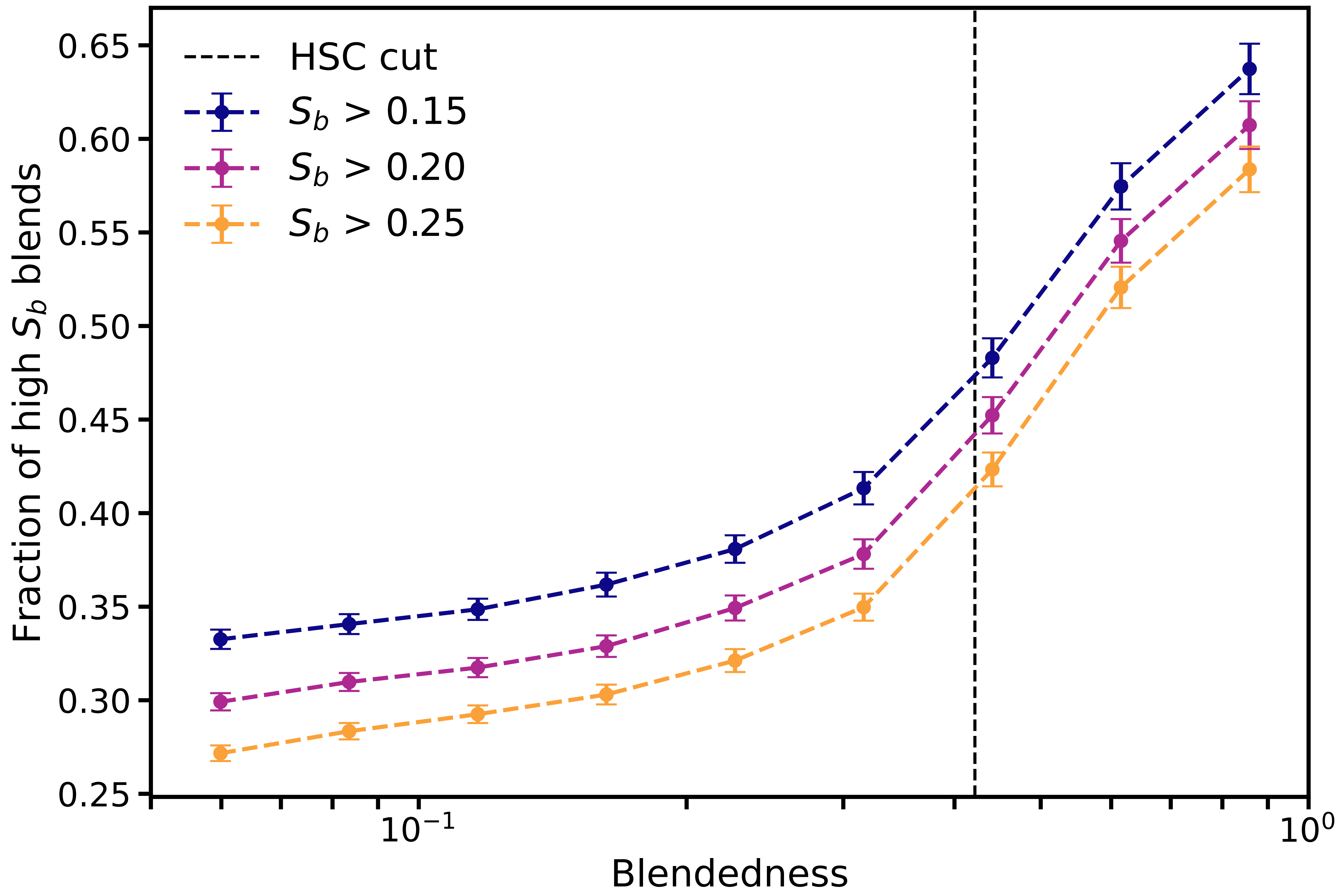
Object vs. object metric

$b = 0 \rightarrow$ **isolated** object

$b = 1 \rightarrow$ completely **blended**

Higher blendedness = higher blending entropy





Cannot differentiate 1-1 systems from unrecognized blends

Blending entropy properties

New efficient metric to characterize blended systems

- **Continuous** measure of blending severity
- Combination of **position** + **shape** + **magnitude** information
- Largely **insensitive** to the cosmoDC2 **magnitude cut** and the choice of the FoF **linking length**
- **Stable** with the DC2object **magnitude** cut
- Uses ***truth*** information: galaxy vs. object metric

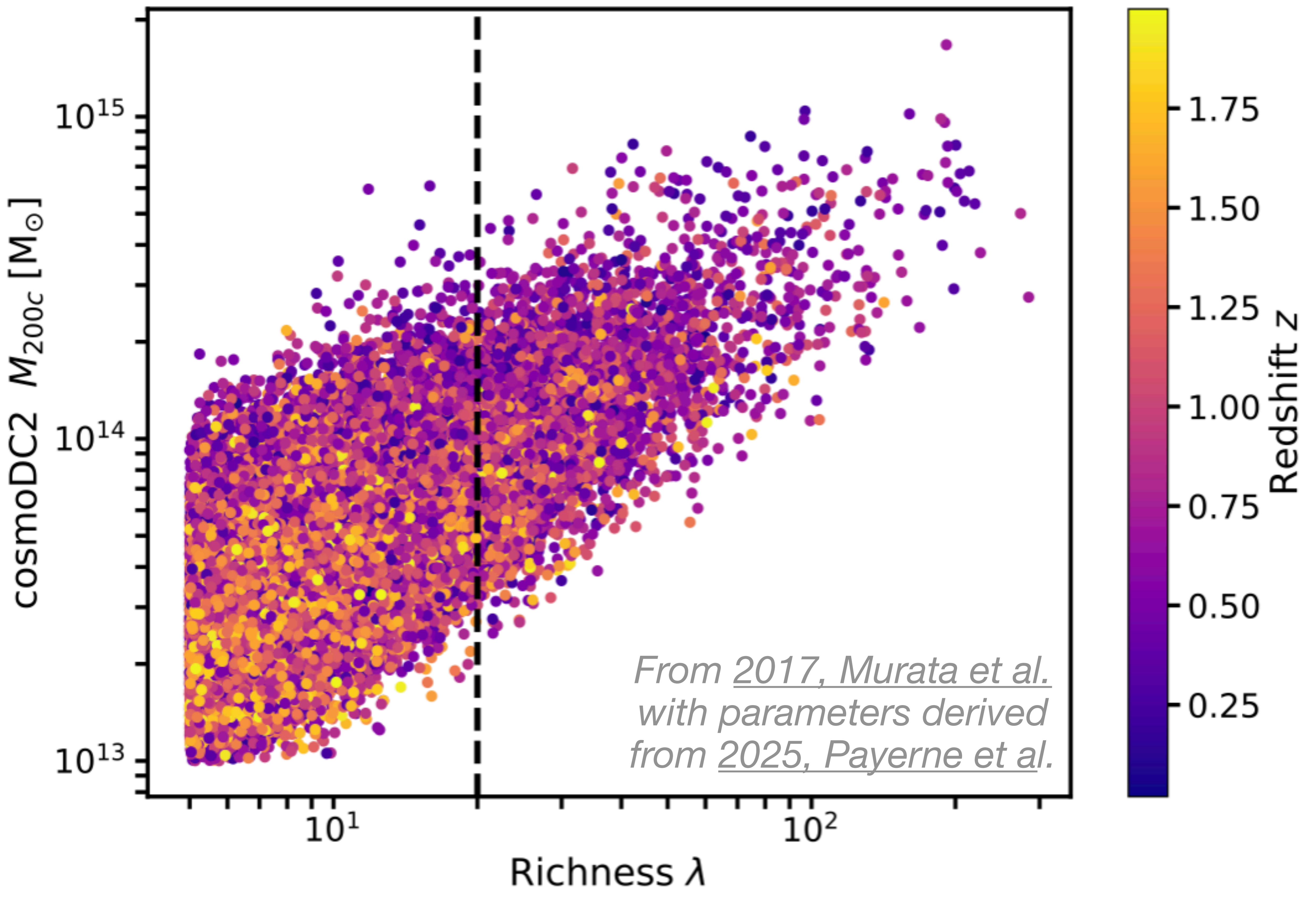
Application to cluster cosmology

Framework

See Constantin's talk!

Set-up

- Lensing around DC2 **dark matter haloes**
  - No detection of galaxy clusters
- Sampling fiducial $M - \lambda$ relation



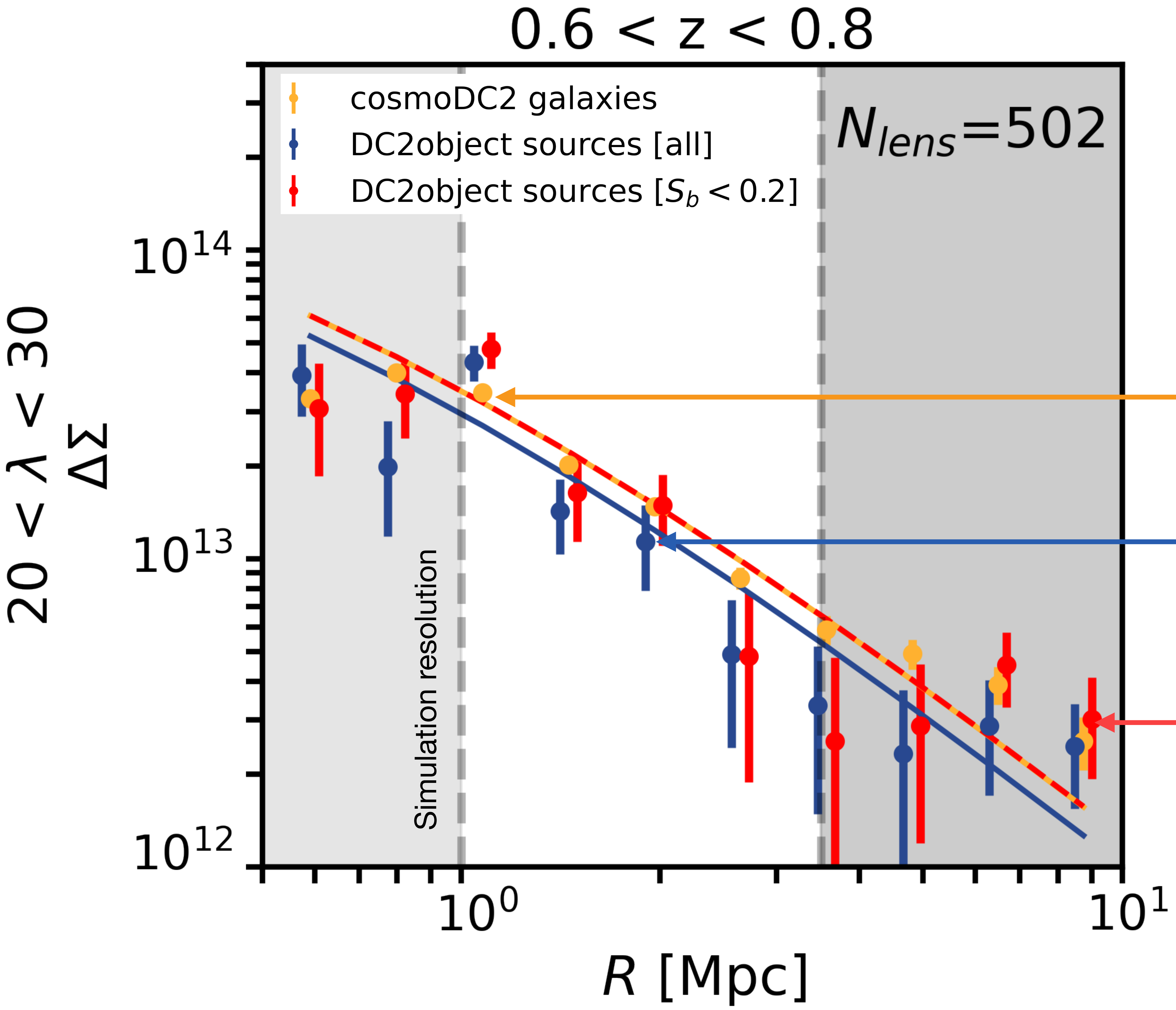
From 2017, Murata et al. with parameters derived from 2025, Payerne et al.

Goal

- Two observables per bins of richness and redshift
  - Haloes **number** and mean **mass**

Impact of blending on lensing profiles

https://github.com/LSSTDESC/CLMM



Removing bad blends

=

Shifting the profiles upwards

=

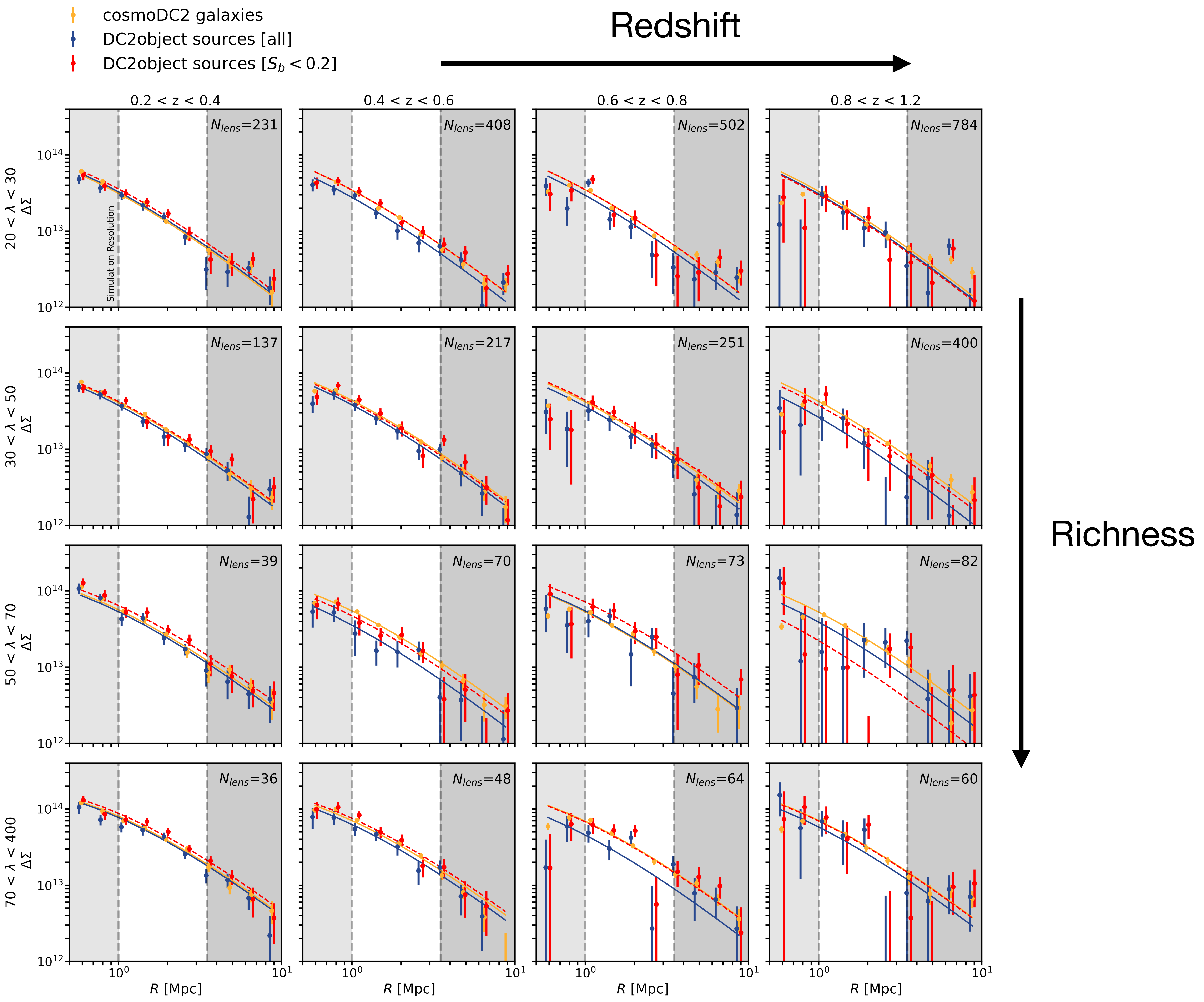
Recovering the true cluster mass

Galaxies (simulated truth)

Objects (simulated observations)

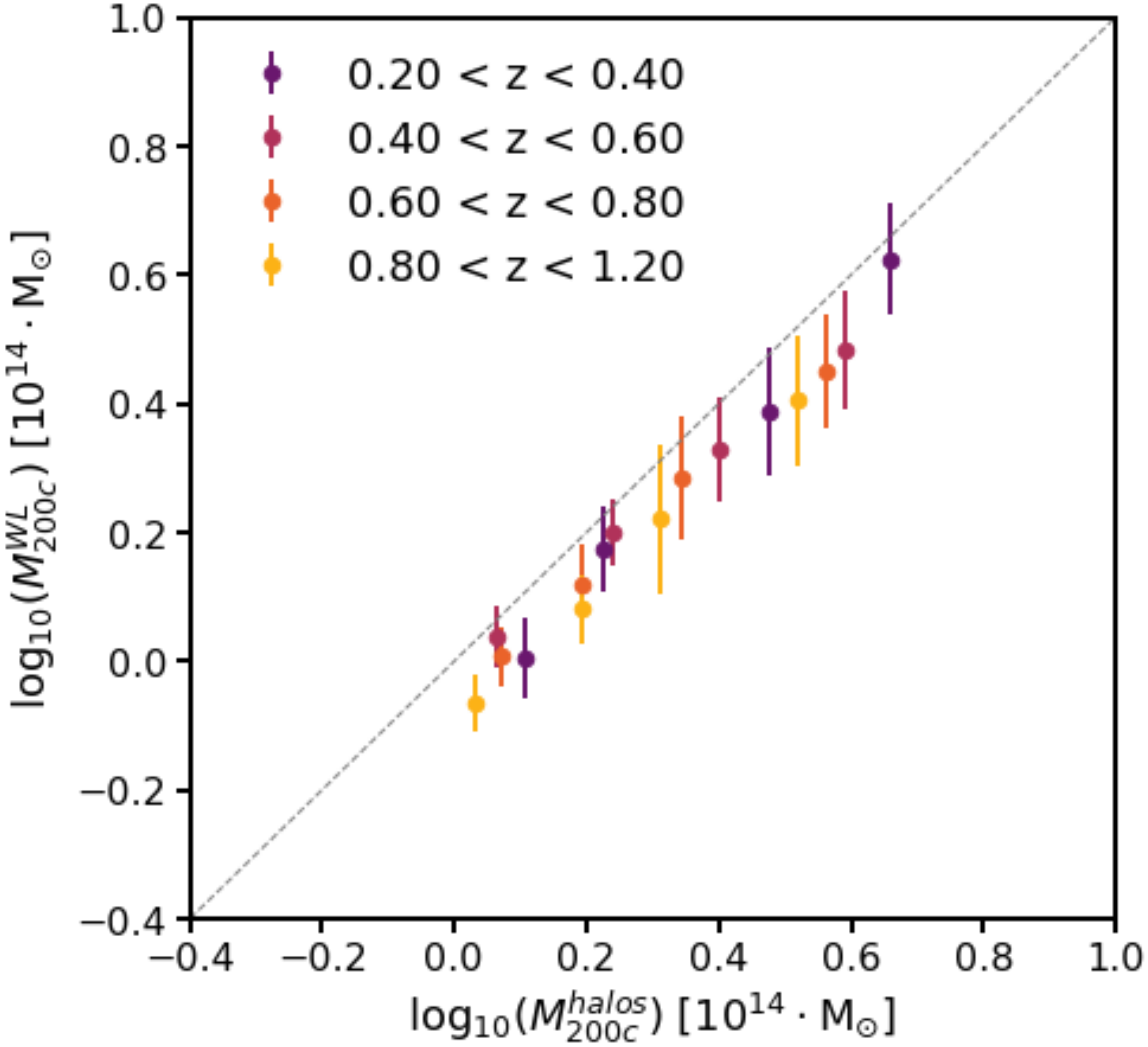
Objects with $S_b < 0.2$ (without blending)

Impact of blending on lensing profiles



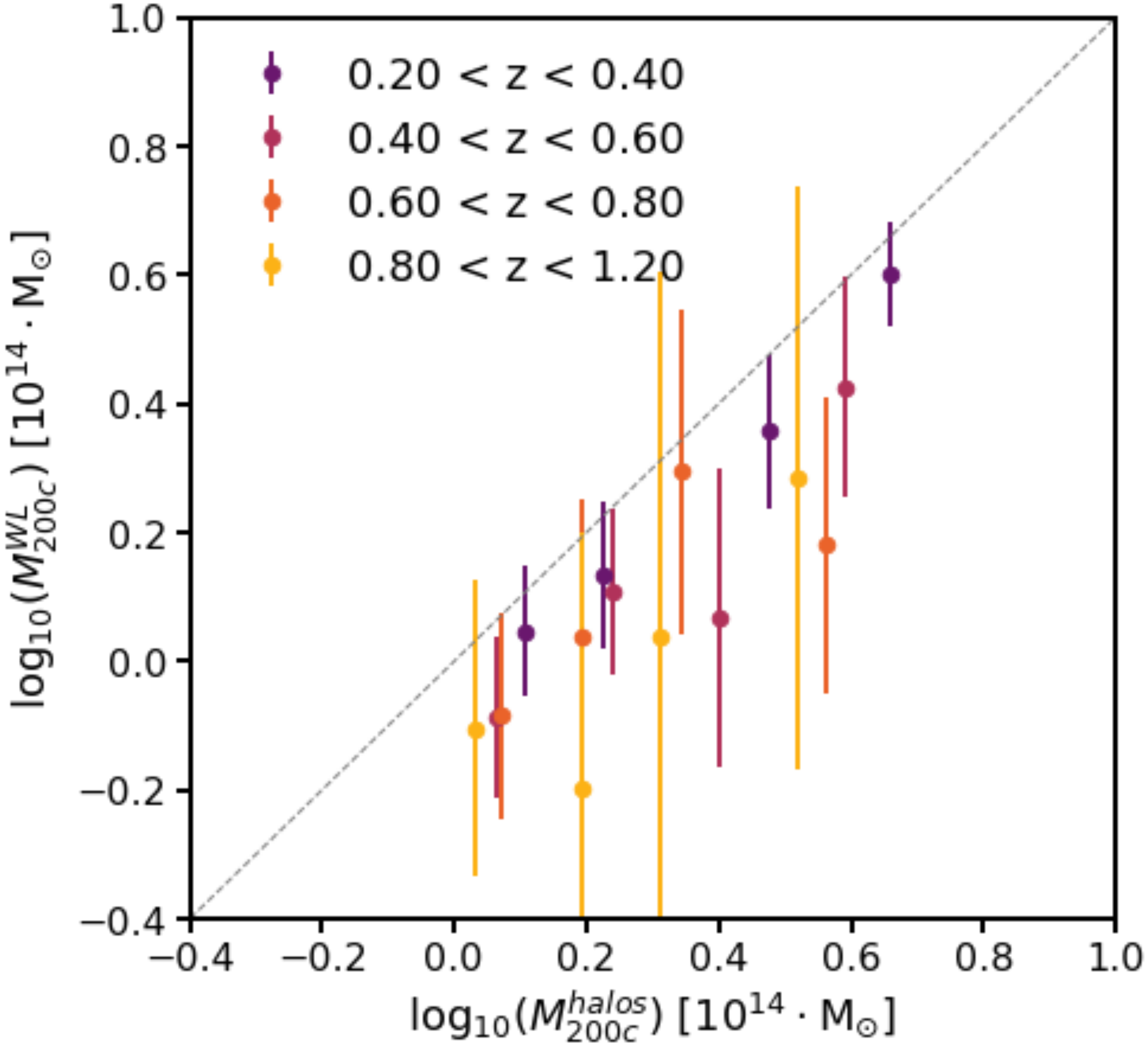
Impact of blending on lensing masses

cosmoDC2



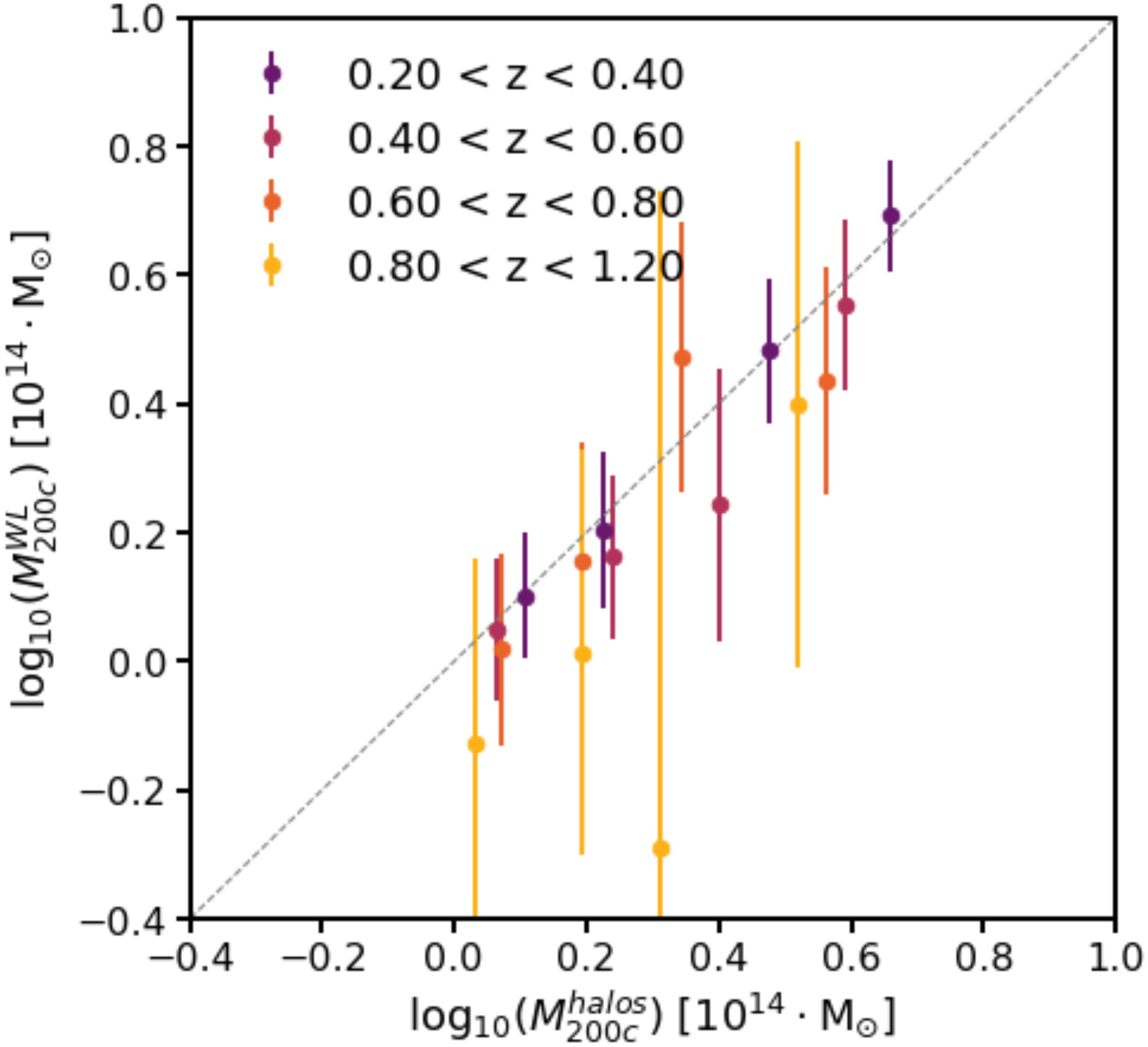
Impact of blending on lensing masses

DC2object with blends



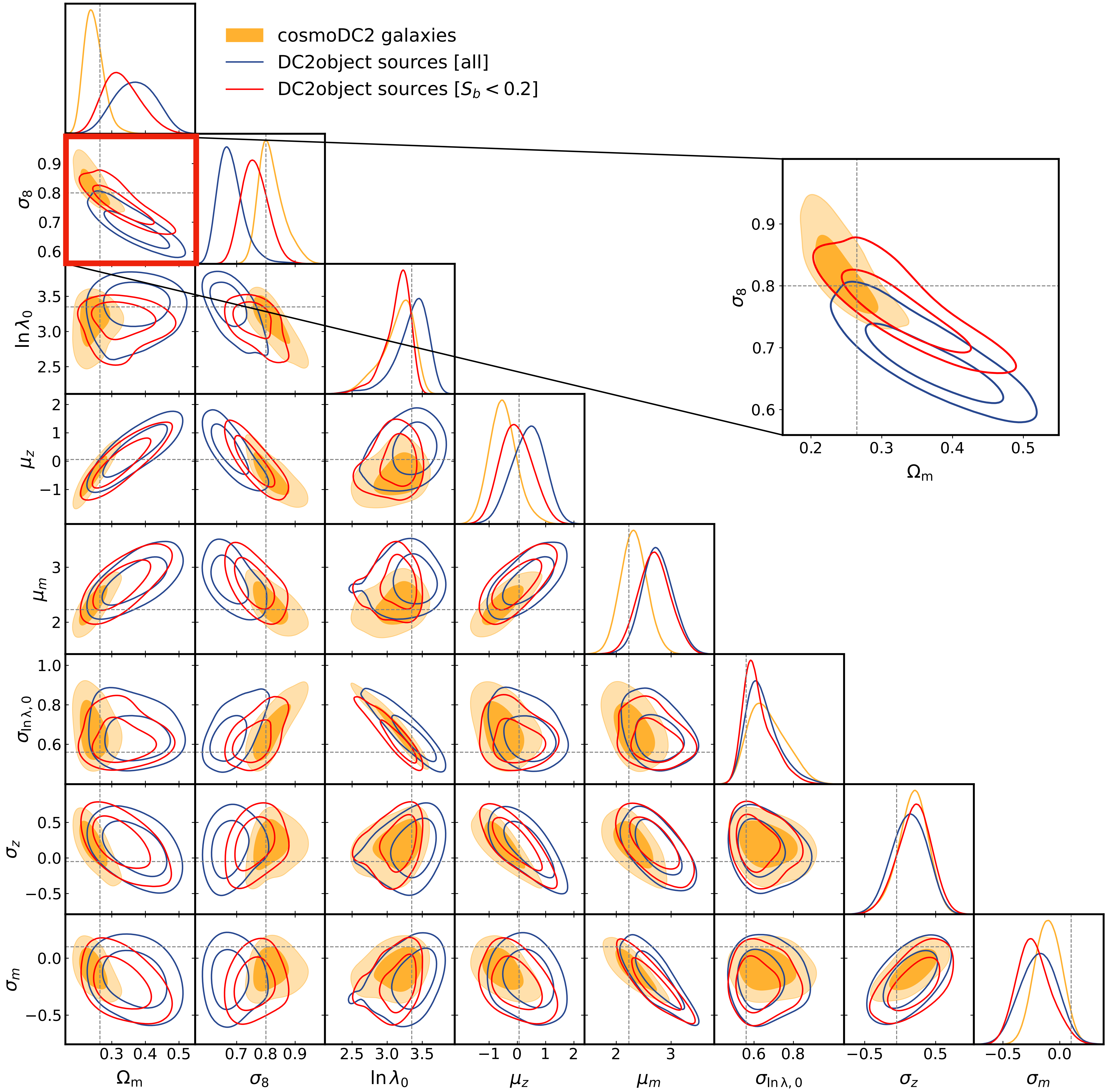
Impact of blending on lensing masses

DC2object without blends



Impact on cosmological parameters

https://github.com/LSSTDESC/CLCosmo_Sim



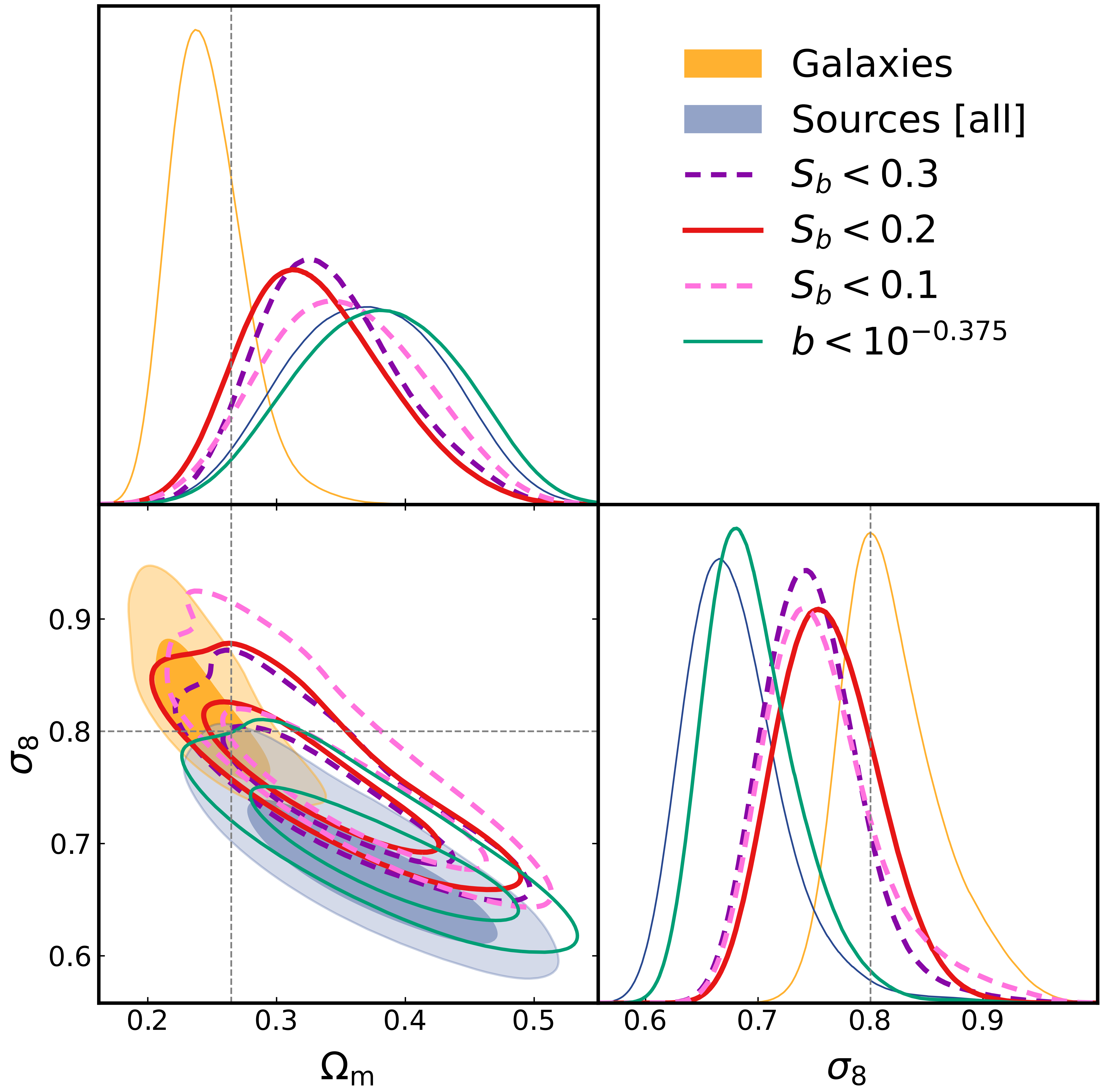
- DC2object contours are shifted toward higher Ω_m and lower σ_8 values compared to cosmoDC2
- The $S_b < 0.2$ cut partially correct the bias

And with a cut on the blendedness?

2018, Mandelbaum et al.

- The HSC blendedness cut is insufficient
- $S_b < 0.1$, $S_b < 0.2$, $S_b < 0.3$ give similar constraints

Metric	Cut	Suppressed WL sources
Blending entropy	< 0.2	23 %
Blending entropy	< 0.1	29 %
Blending entropy	< 0.3	17 %
Blendedness	$< 10^{-0.375}$	5 %



Conclusions

1. **Development of a new matching method to identify blends**
    - Relative probabilities of matching
    - Blending entropy to separate highly vs. well-matched systems

2. **Impact of blending on cluster lensing profiles**
    - Profiles biased low due to blending
    - Masses partially recovered by removing bad blends
    - Impact of blending on cosmological parameters

3. **Application to data**
    - Mitigation strategy, calibrated on overlapping sky areas with LSST (including deep fields/space data)
    - Ongoing work combining LSST ComCam and HST data
    - Application to 3x2pt

Draft of the paper was sent to collaborators and will be soon in IR!