Impact of blending on weak lensing measurements with Rubin/LSST

mm Universe, June 2023

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Cosmology with galaxy clusters

Millennium 2005, Springel et al. *SMACS 0723 - JWST*

Largest gravitationally bound structures in the Universe

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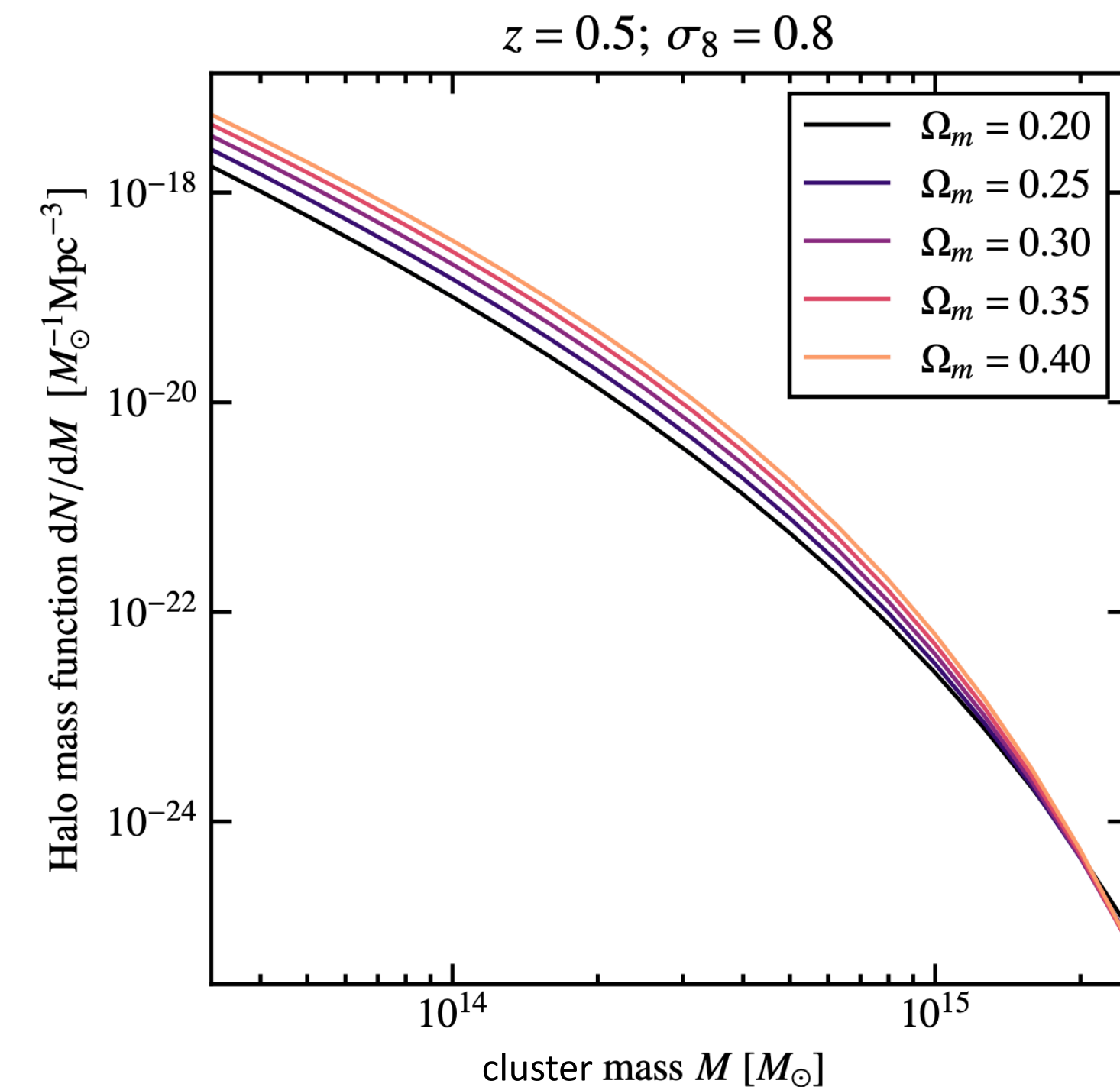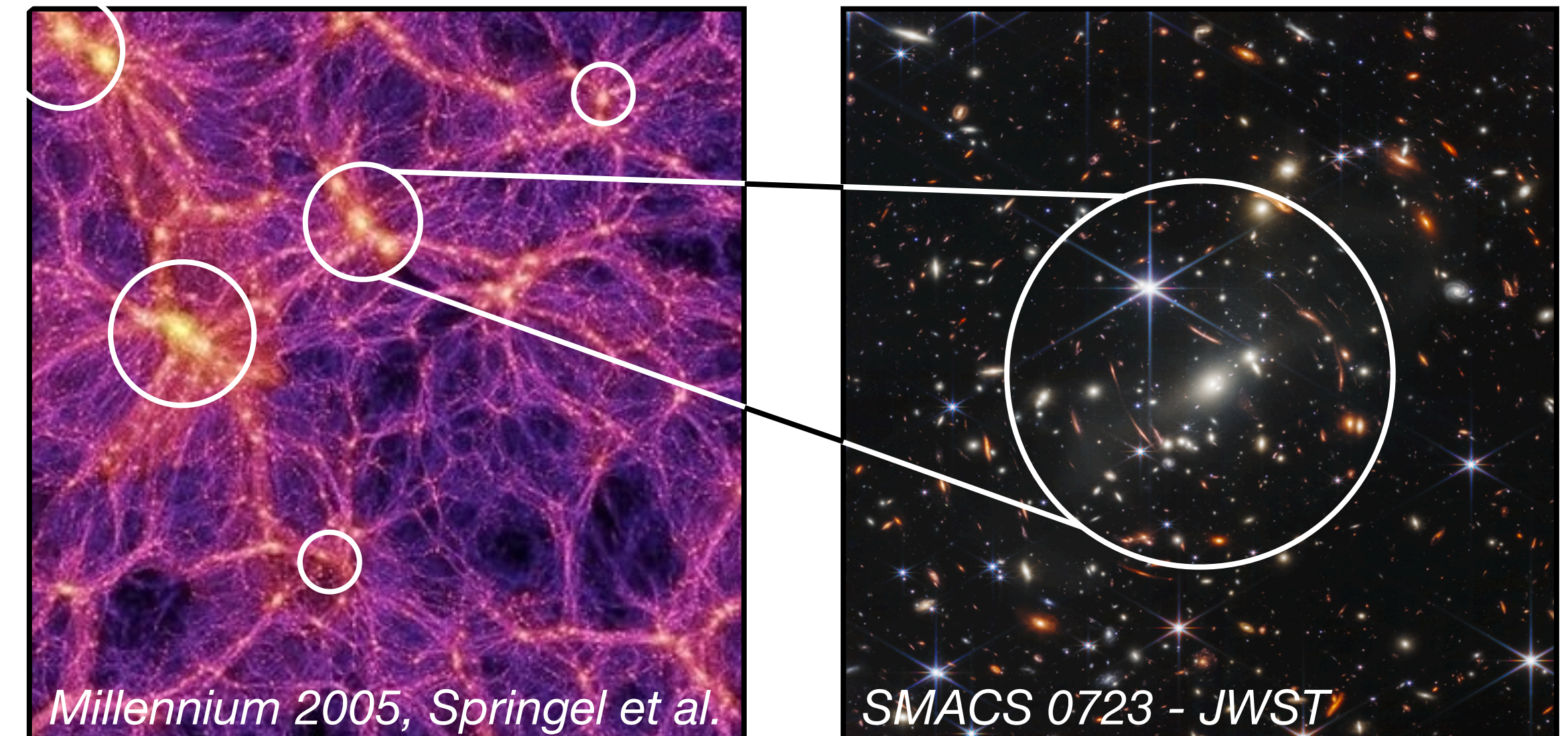- 50 to 1000 galaxies
- $M > 10^{13.5} M_\odot$, $z < 3$

Tracers of the matter over-densities

- Abundance depends on cosmology

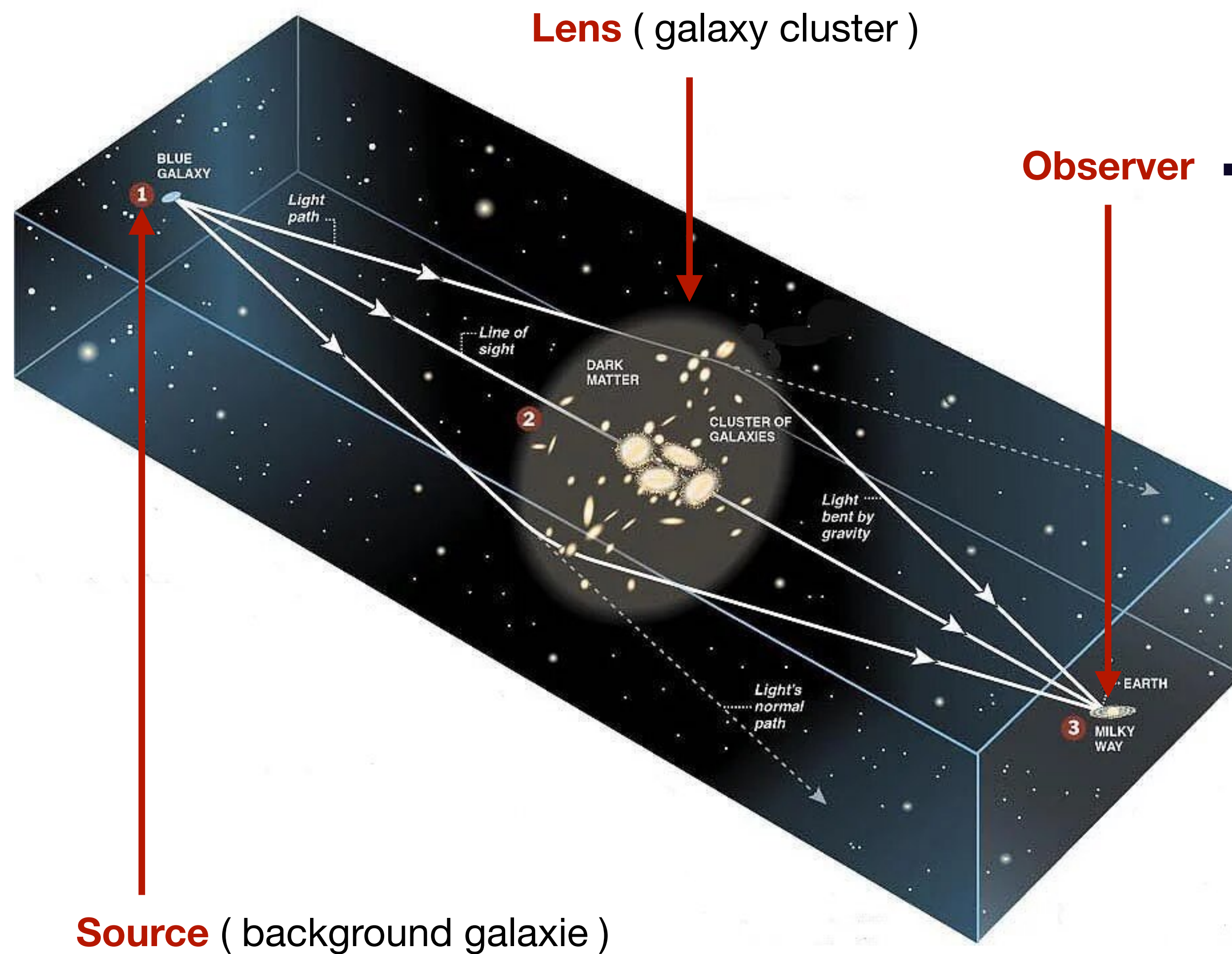**Studied through their counting per bins of mass and redshift**

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

Mass is not an observable: indirect measurements
through weak lensing

$z = 0.5$; $\sigma_8 = 0.8$
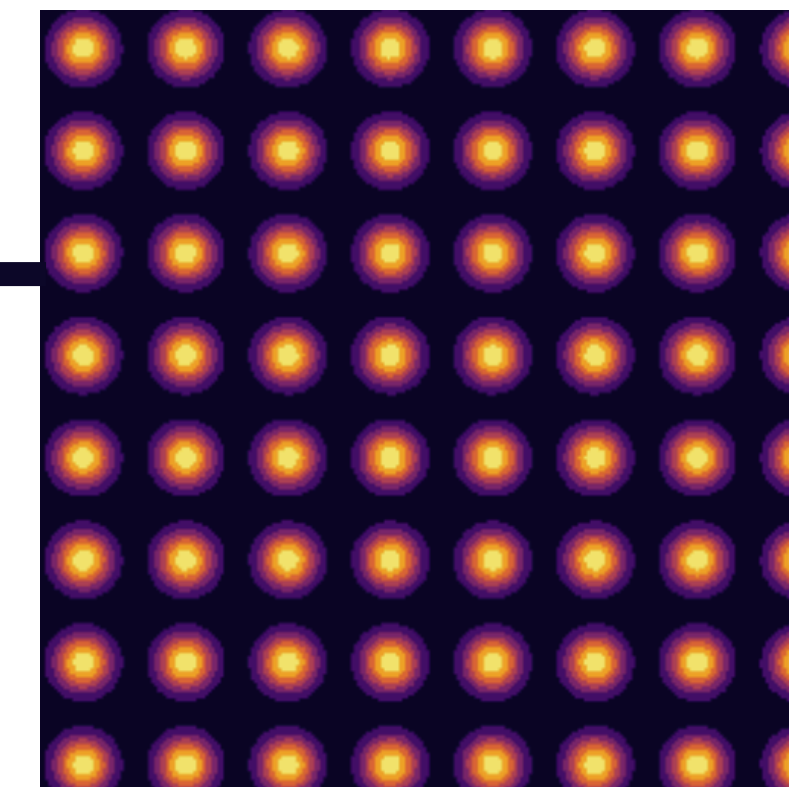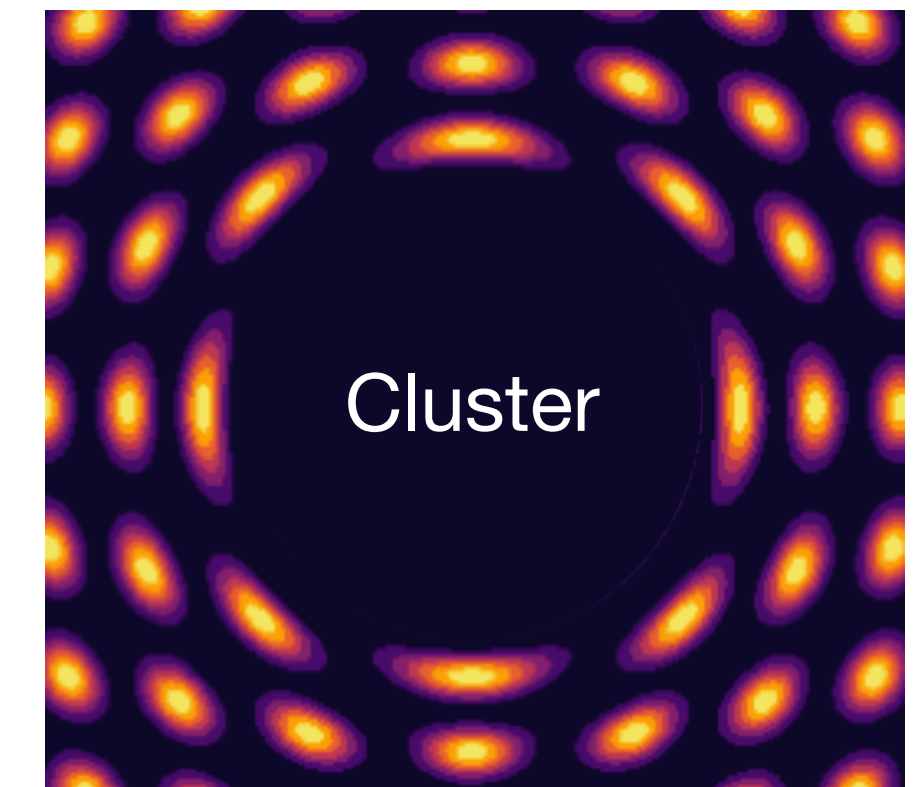
——	$\Omega_m = 0.20$
——	$\Omega_m = 0.25$
——	$\Omega_m = 0.30$
——	$\Omega_m = 0.35$
——	$\Omega_m = 0.40$

Halo mass function dN/dM $[M_\odot^{-1} \mathrm{Mpc}^{-3}]$

cluster mass M $[M_\odot]$

Weak gravitational lensing

Lens (galaxy cluster)

Observer

Source (background galaxie)

BLUE GALAXY

Light path

Line of sight

DARK MATTER

CLUSTER OF GALAXIES

Light bent by gravity

Light's normal path

EARTH

MILKY WAY

UNLENSED

LENSED

Cluster

Galaxy shapes are used to measure the *lensing shear*

Weak gravitational lensing

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

$$\Delta\Sigma(R, z_l) = \langle \underline{\Sigma_{crit}(z_{gal}, z_l)} \; \underline{\epsilon_+^{obs}} \rangle \qquad \text{Average on many galaxies}$$

Critical surface mass density   Tangential ellipticity

needs   needs

redshifts   shapes

Fit of $\Delta\Sigma$ = Estimate of galaxy clusters masses

Mock CLMM
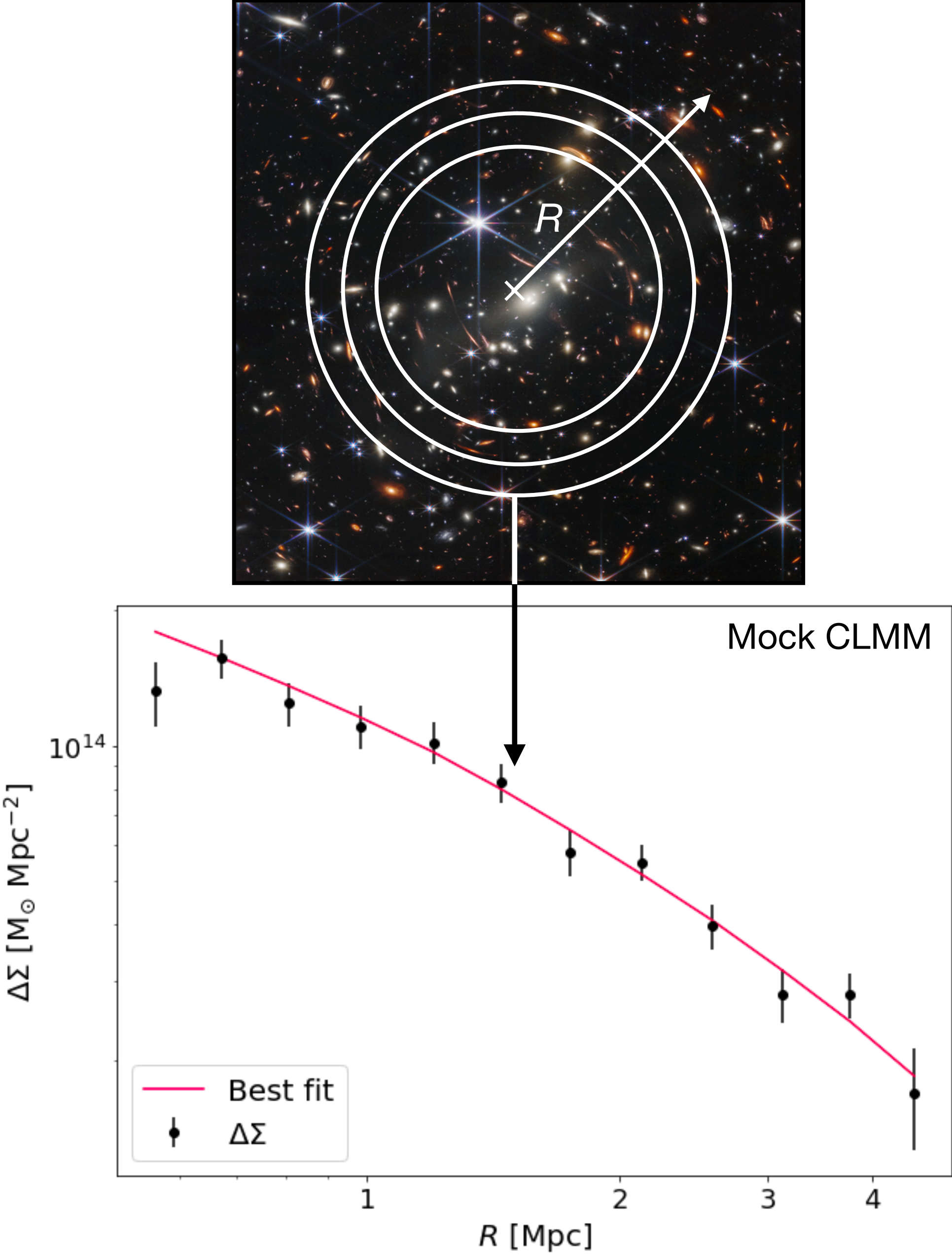
Vera C. Rubin - LSST

Vera C. Rubin Observatory

- World's largest camera (3 billions pixels)
- 8-diameter primary mirror
- 0.2 arcseconds per pixel

Legacy Survey of Space and Time - LSST

- **Optical** and **deep** sky survey over 10 years
- Footprint of 18,000 $\deg^2$
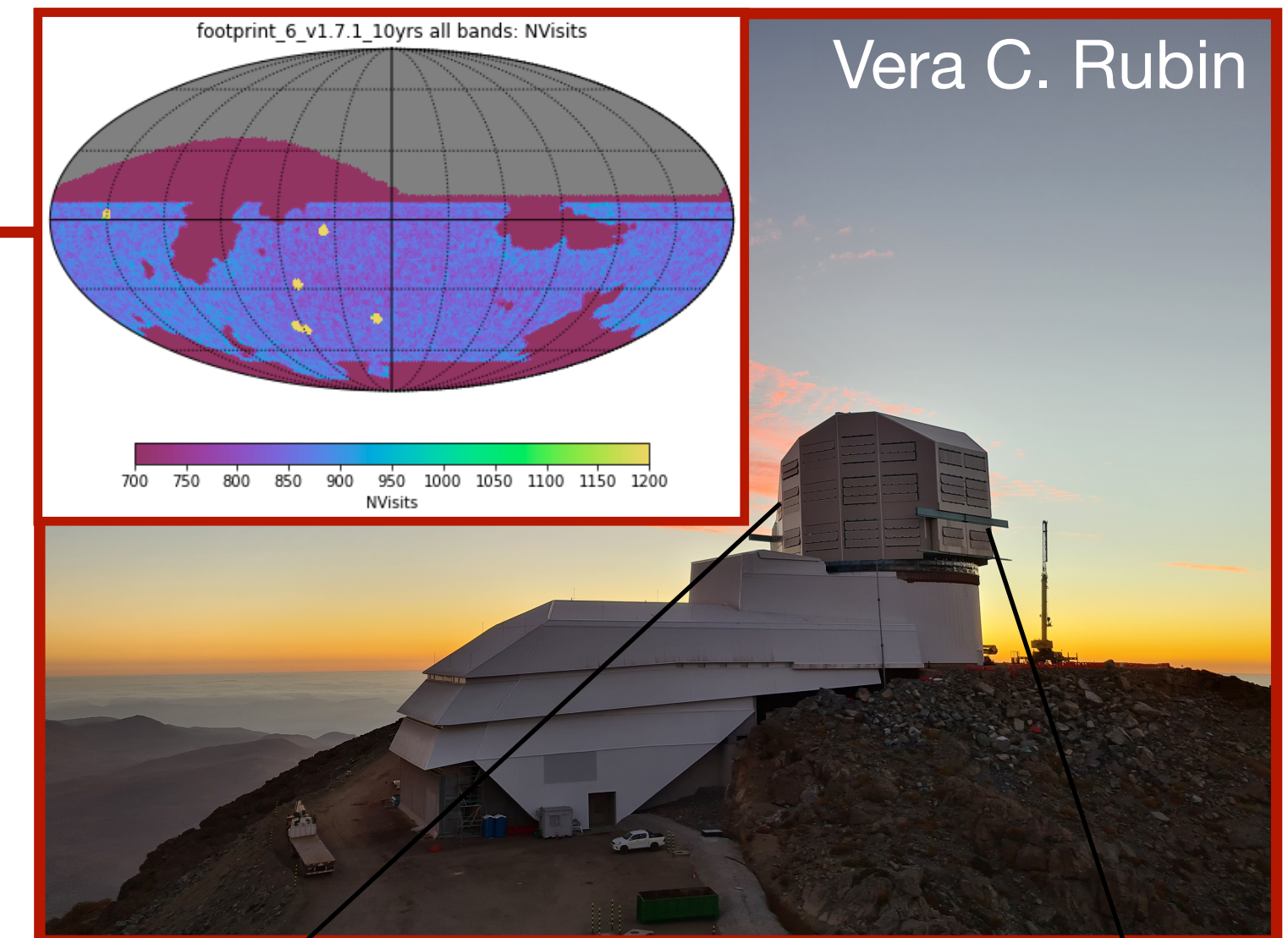- First scientific data in **2024**

DES	LSST
0.5 billion	10 billions of galaxies
redshift ≤ 1.5	redshift ≤ 3
magnitude ≤ 23	magnitude ≤ 27

International scientific collaboration **DESC**

- ~ 1000 members, 20 countries

Vera C. Rubin

LSST camera

Blending

Superposition of galaxies on the images due to:

- the **depth** of observation
- the **atmosphere**
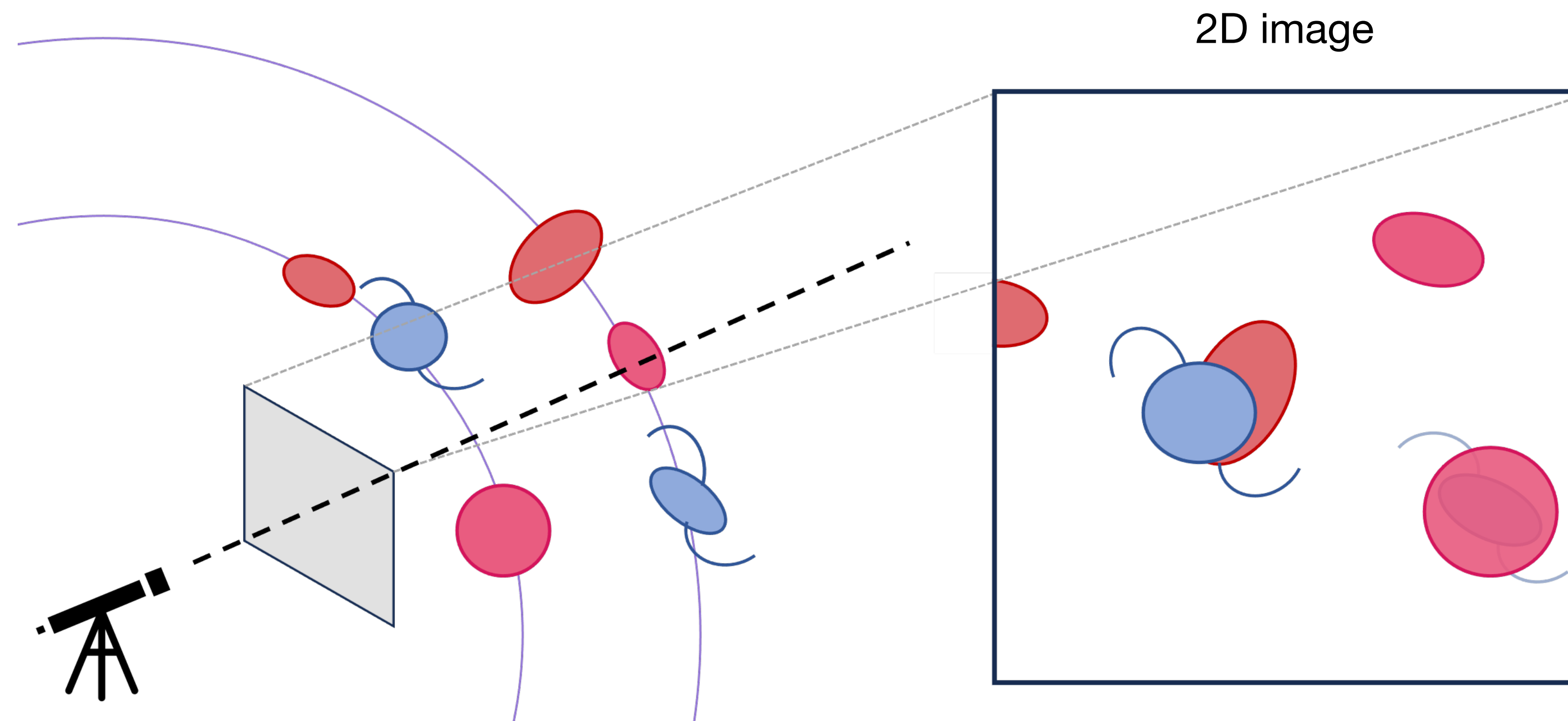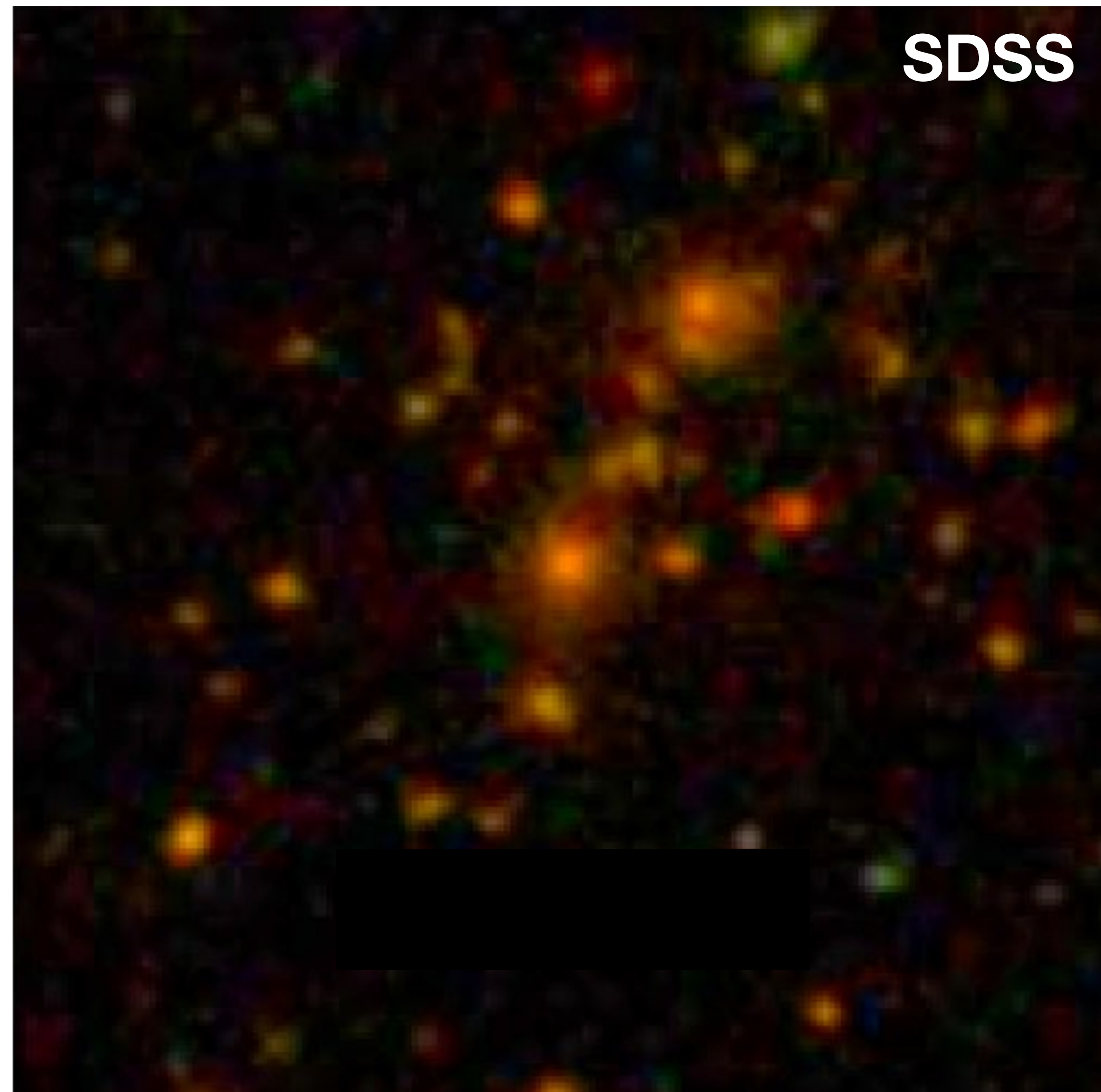
2D image

Blending

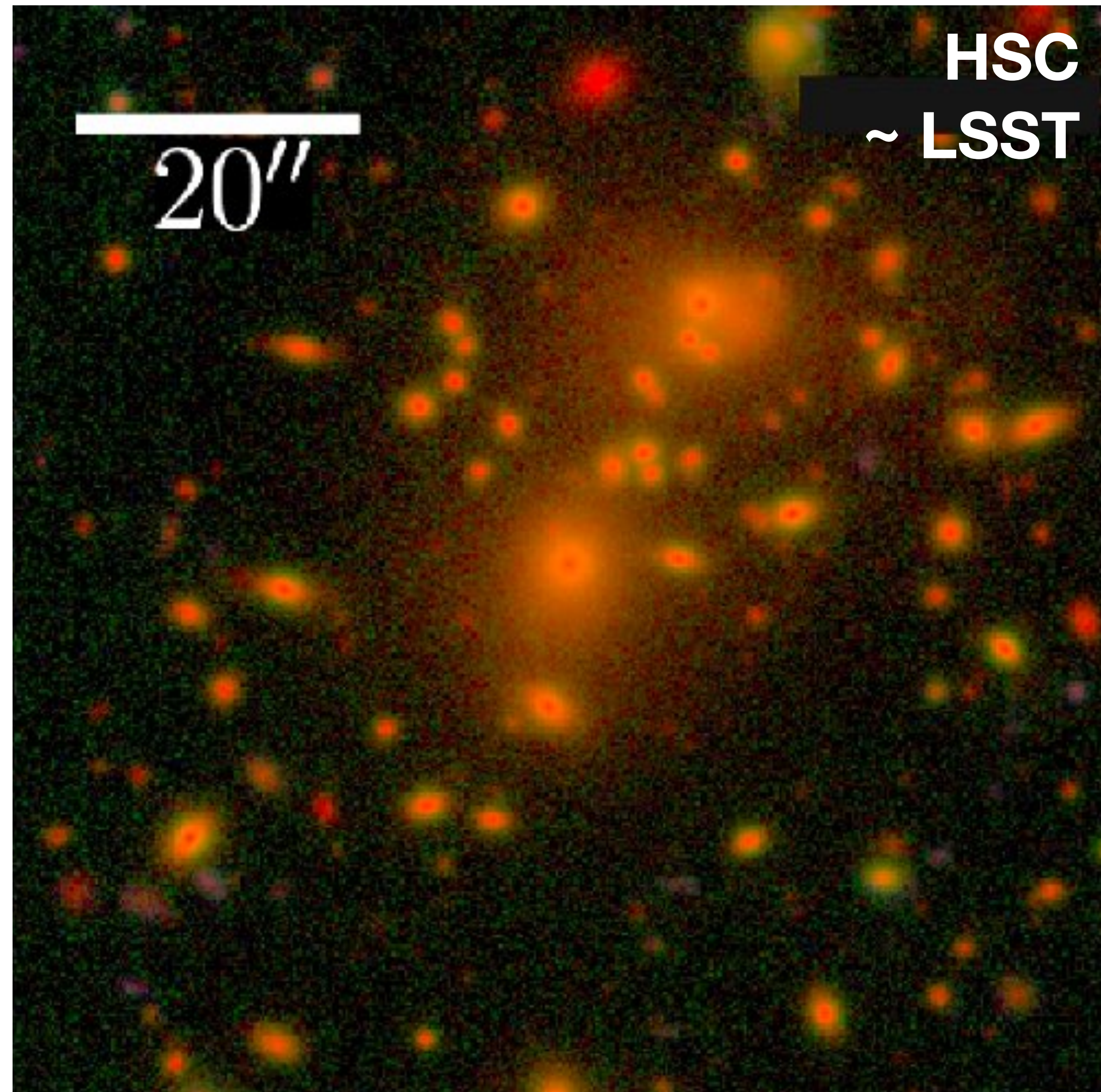
SDSS

2018, Huang et al.

Blending

HSC
~ LSST

20″

2018, Huang et al.
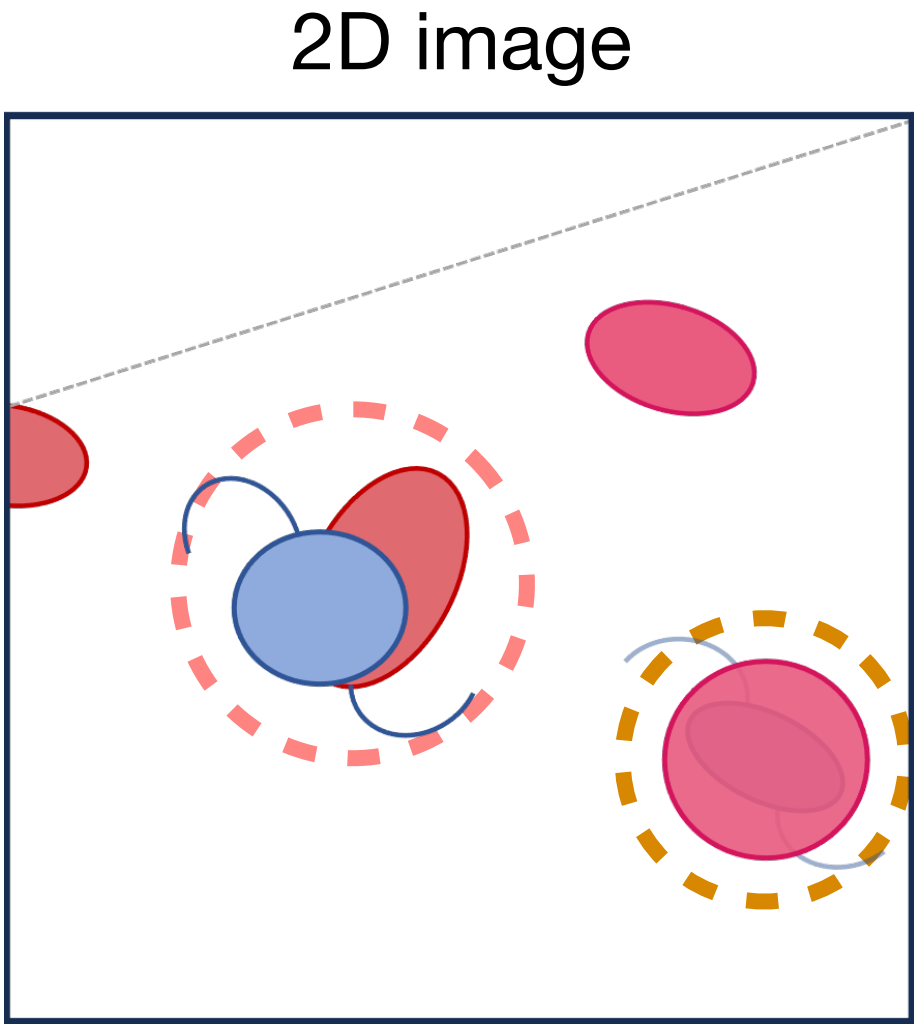
Blending

Recognized blends

Hubble/ACS

2021, Shibuya et al.
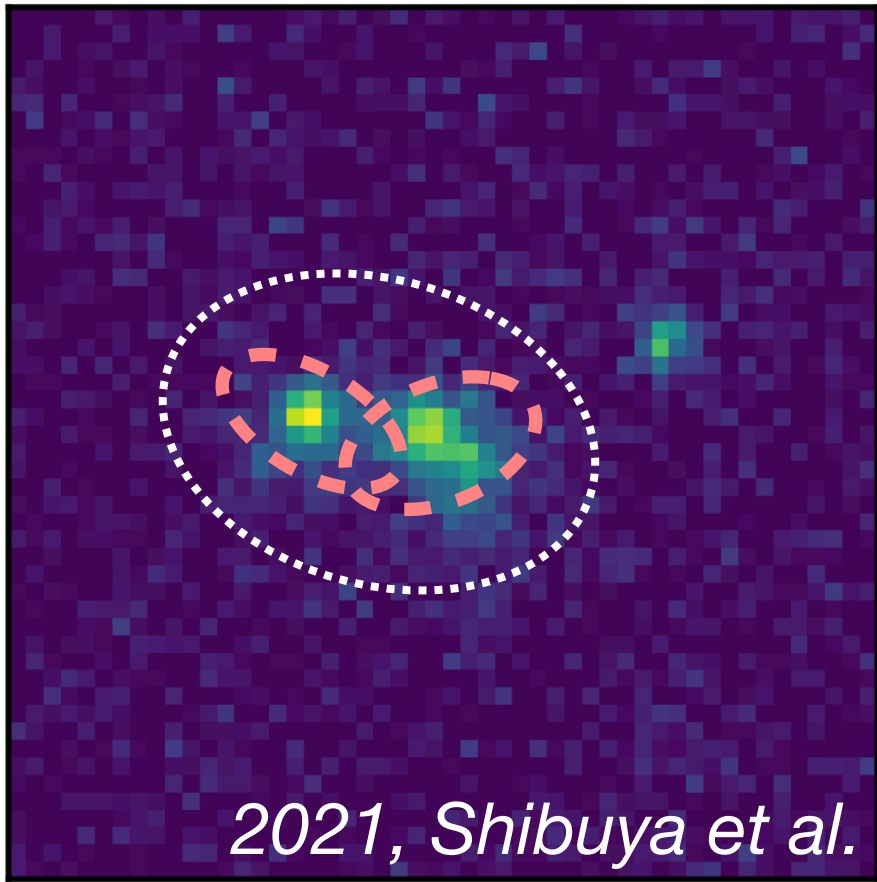
2D image

Less resolution

Unrecognized blends

Subaru/HSC

1 arcsec
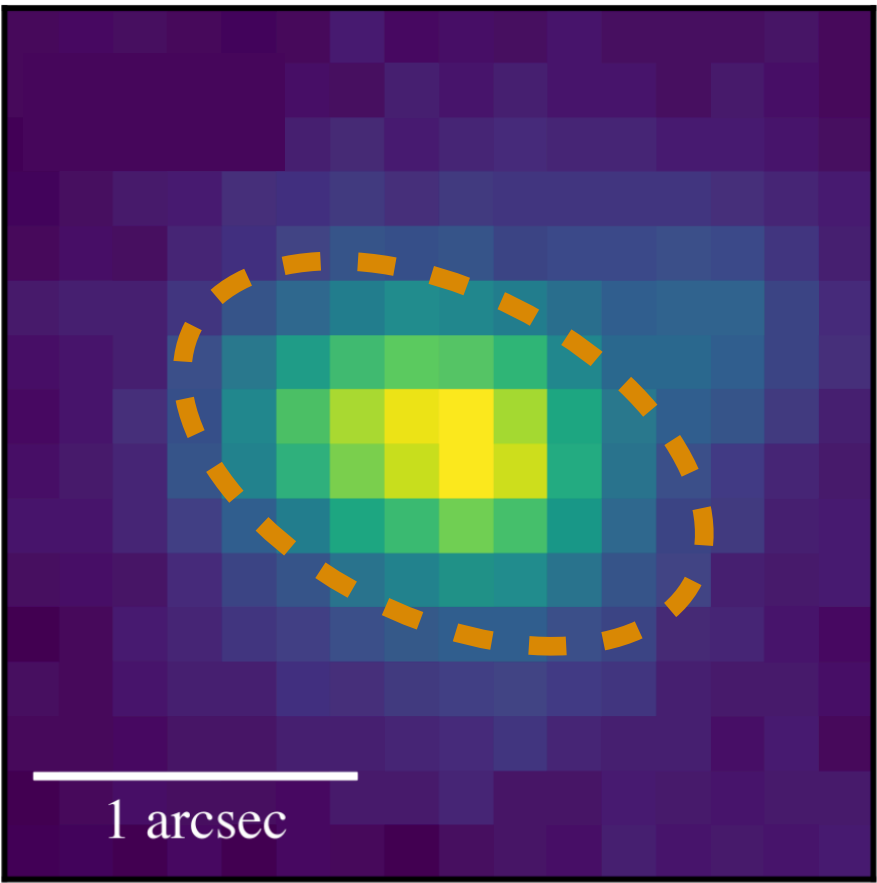
LSST deblender: **SCARLET**

Source separation in multi-band images

HSC image | SCARLET model | Residuals

2018, Melchior et al.
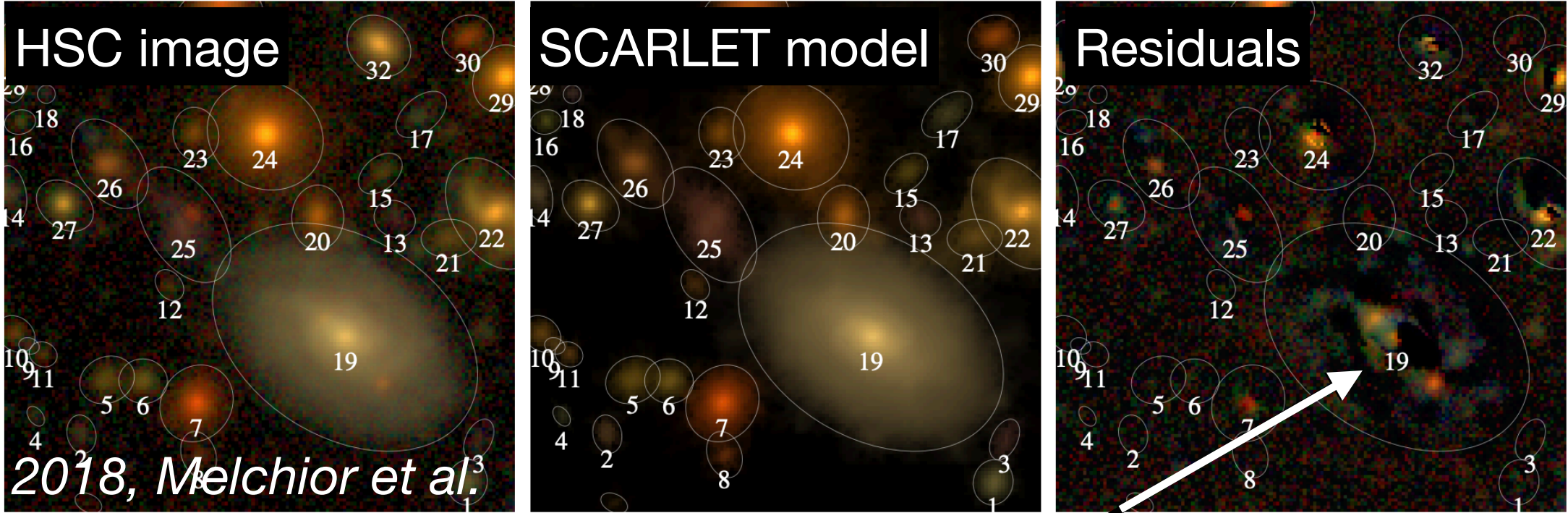
Imperfect deblending

- Recognized blends: **~40 %**

- Unrecognized blends: **~14 - 20 %***
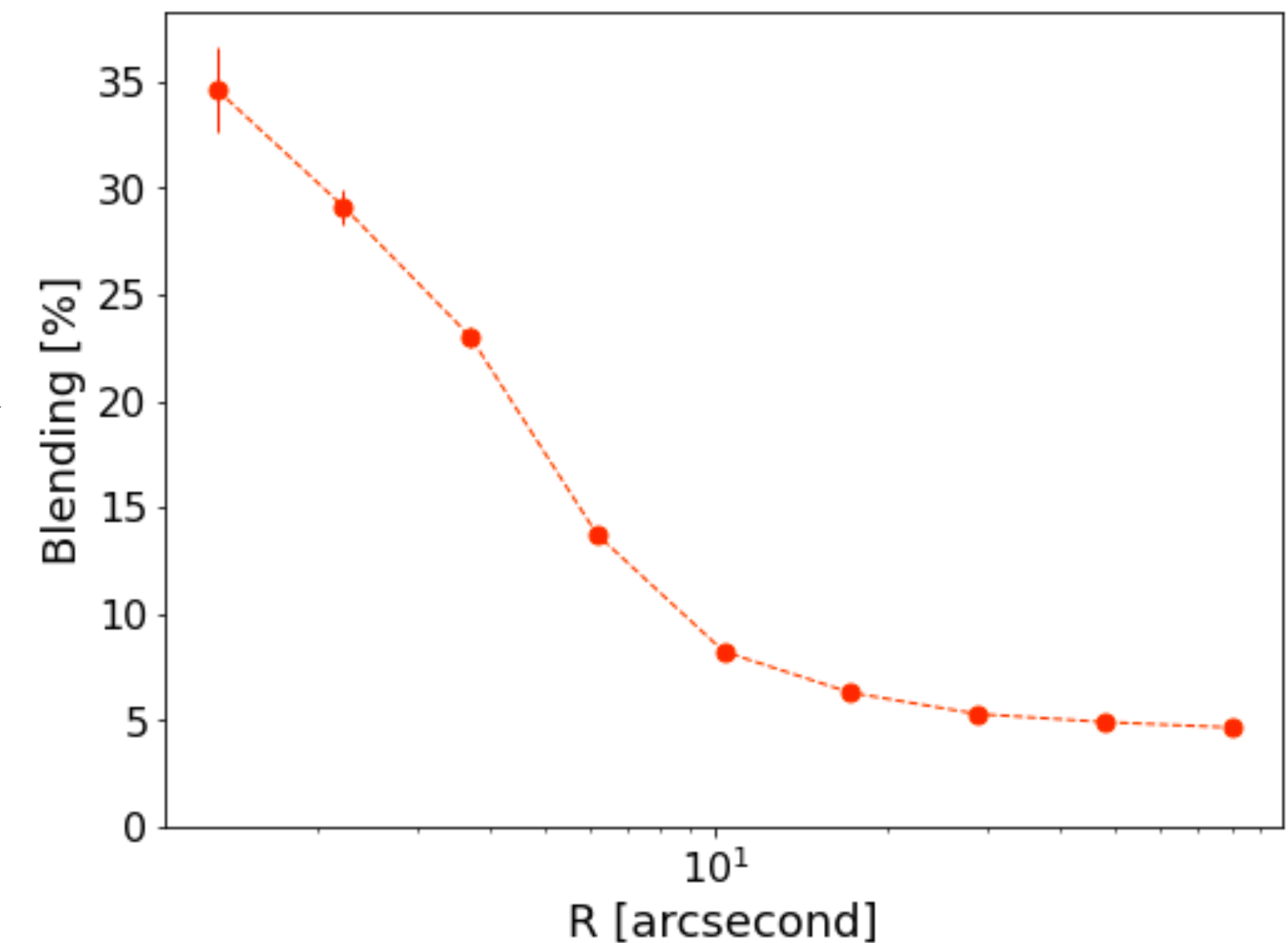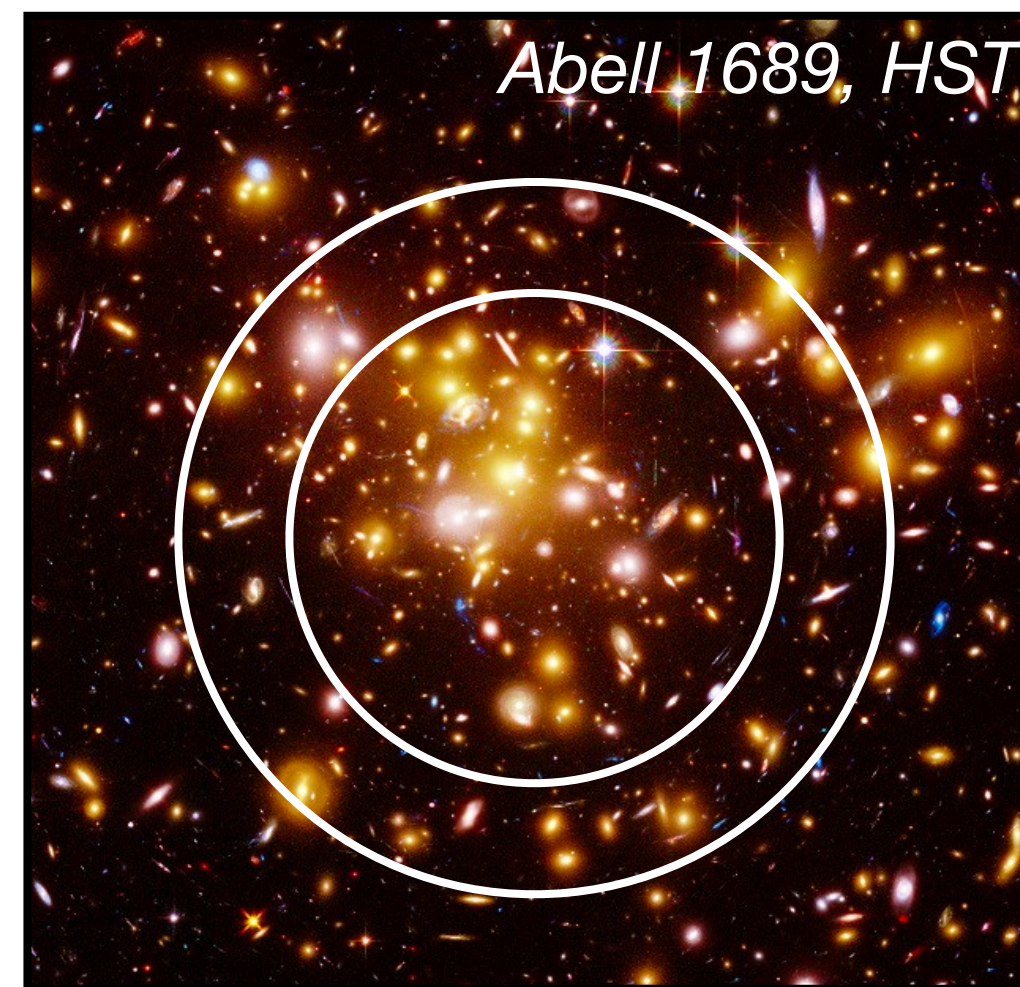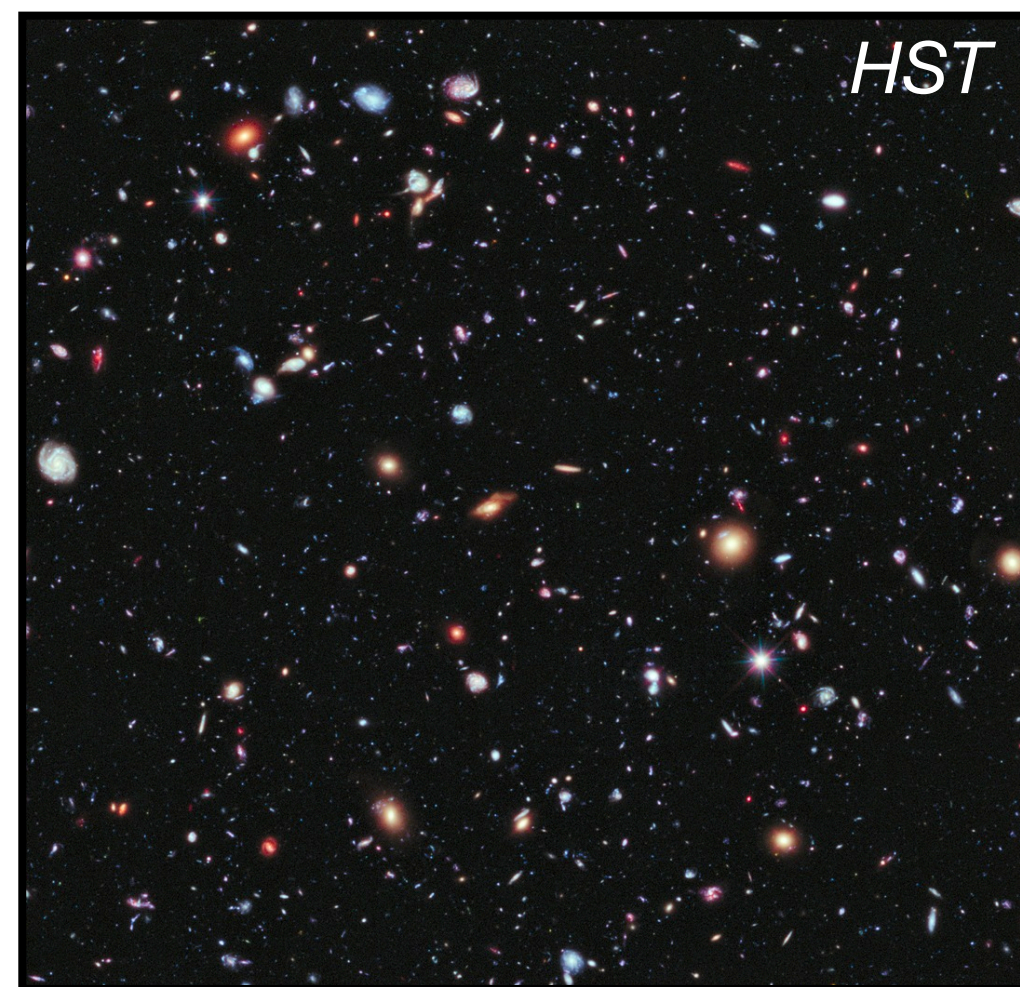
* *2016, Dawson et al.*
2022, Troxel et al.

Blending around galaxy clusters

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

High amount of blending near clusters centres

OUTSIDE

INSIDE

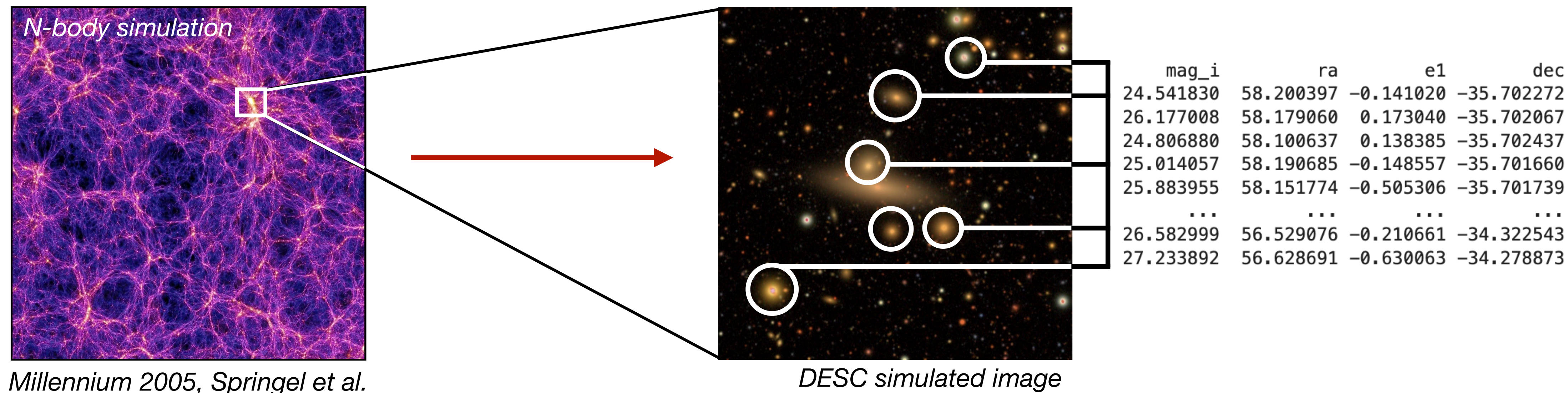Blending impacts the **detection** of galaxies and the measurement of galaxy **shapes**

Blending will impact future Rubin/LSST weak lensing data induced by massive clusters

Tools and pre-work

Simulated catalogs

N-body simulation

Millennium 2005, Springel 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
24.806880	58.100637	0.138385	−35.702437
25.014057	58.190685	−0.148557	−35.701660
25.883955	58.151774	−0.505306	−35.701739
...	...	...	...
26.582999	56.529076	−0.210661	−34.322543
27.233892	56.628691	−0.630063	−34.278873

cosmoDC2 = **truth** catalog

- 440 deg^2 catalog from a N-body simulation

- Reference for **galaxies** and dark matter haloes

- mag $<$ 30, z $=$ 3
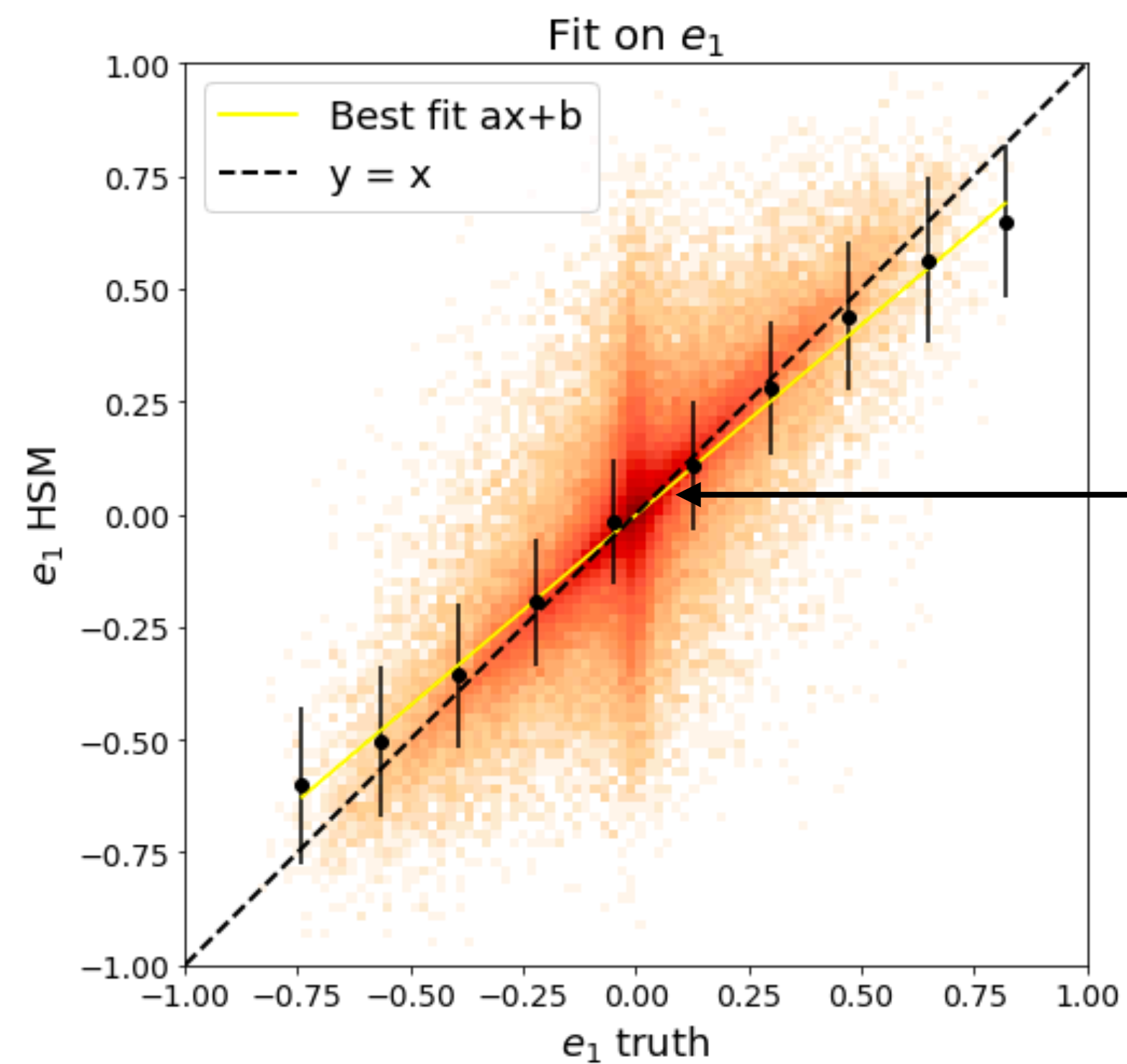
DC2object = **object** catalog

- Simulated images from cosmoDC2

- Detection of **objects**

- Measured positions, magnitudes ($<$ 28), shapes…

Identification of blends through catalog matching

HSM calibration and DC2 photometric redshifts

$$\Delta\Sigma(R, z_l) = \langle \Sigma_{crit}(z_{gal}, z_l) \, \boxed{\epsilon_+^{obs}} \rangle$$

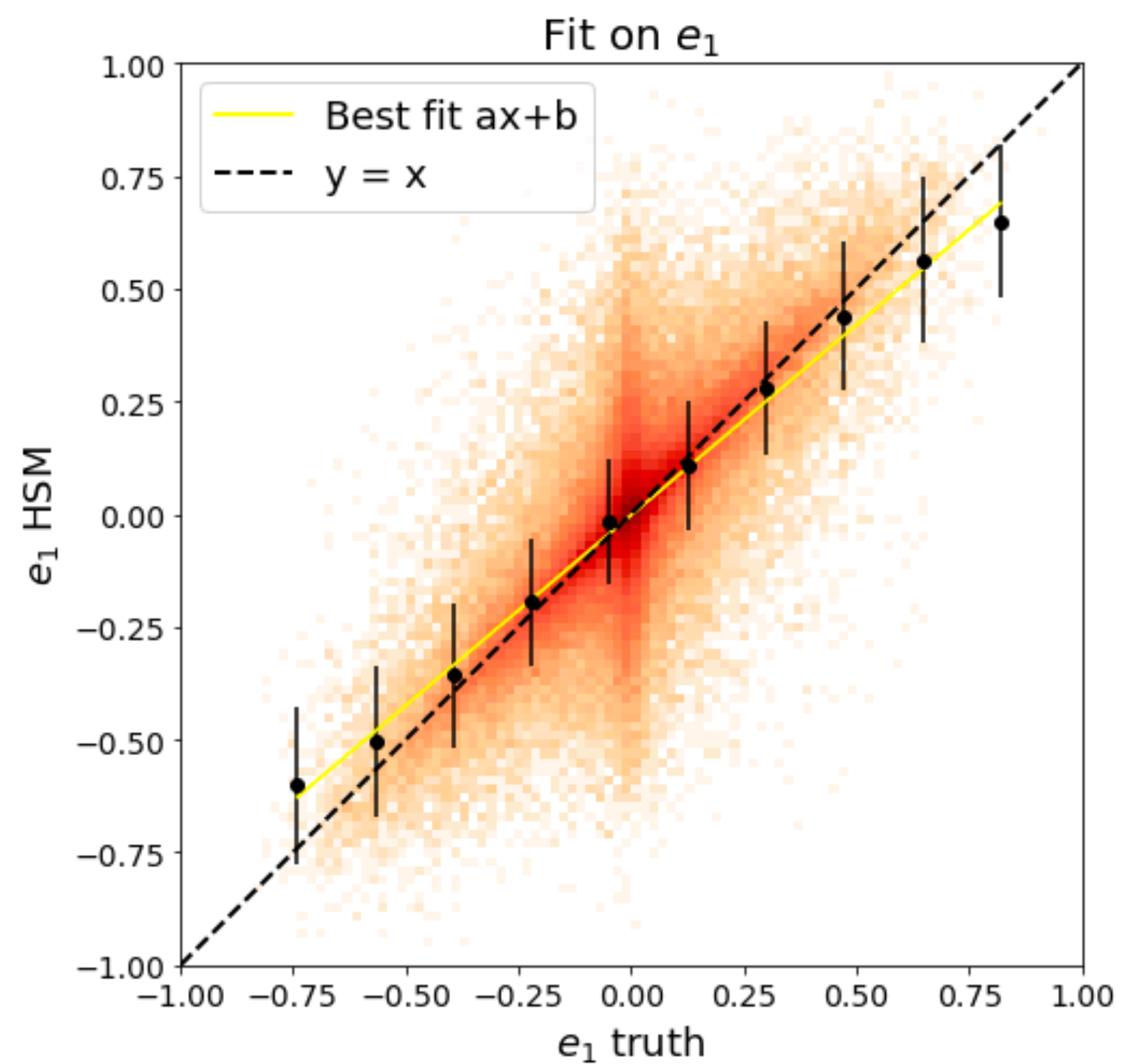**HSM ellipticities calibration**
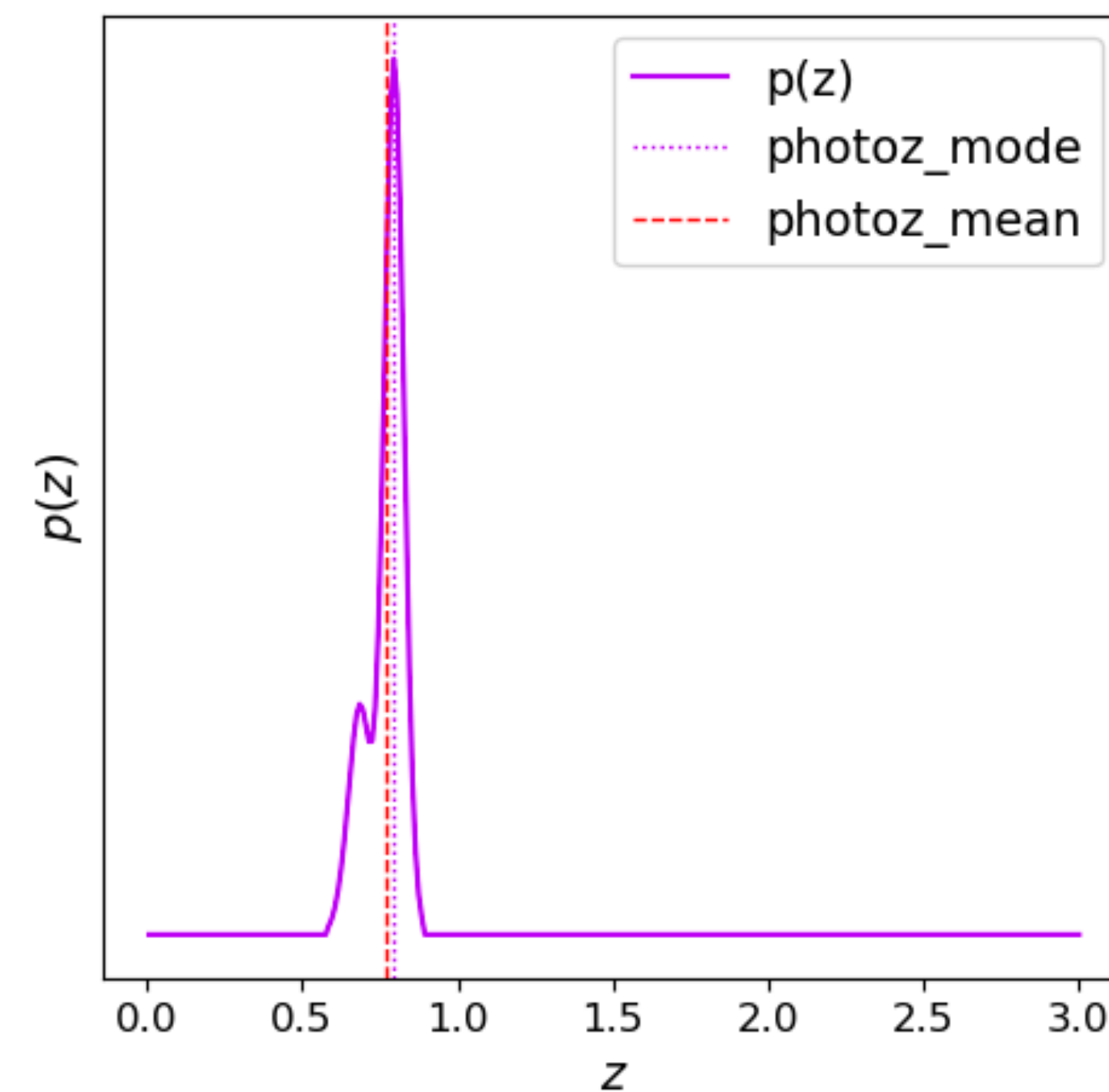

$$e_{HSM} = 0.85 \times e_{truth} - 0.003$$

HSM calibration and DC2 photometric redshifts

$$\Delta\Sigma(R, z_l) = \langle \Sigma_{crit}(z_{gal}, z_l) \, \epsilon_+^{obs} \rangle$$

HSM ellipticities calibration

Photometric redshifts

Individual errors that we can calibrate → sufficient for blending?
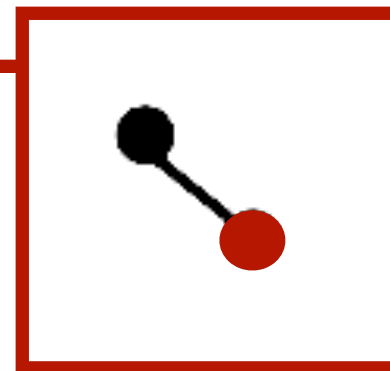
Detection of blends in DC2

Friends-of-Friends

https://github.com/yymao/FoFCatalogMatching

n-m system

n = # of **galaxies** from **cosmoDC2**
m = # of **objects** from **DC2object**

Linking length

Friends-of-Friends

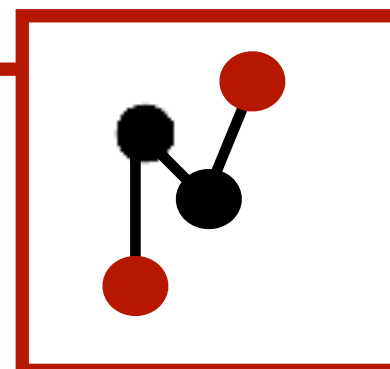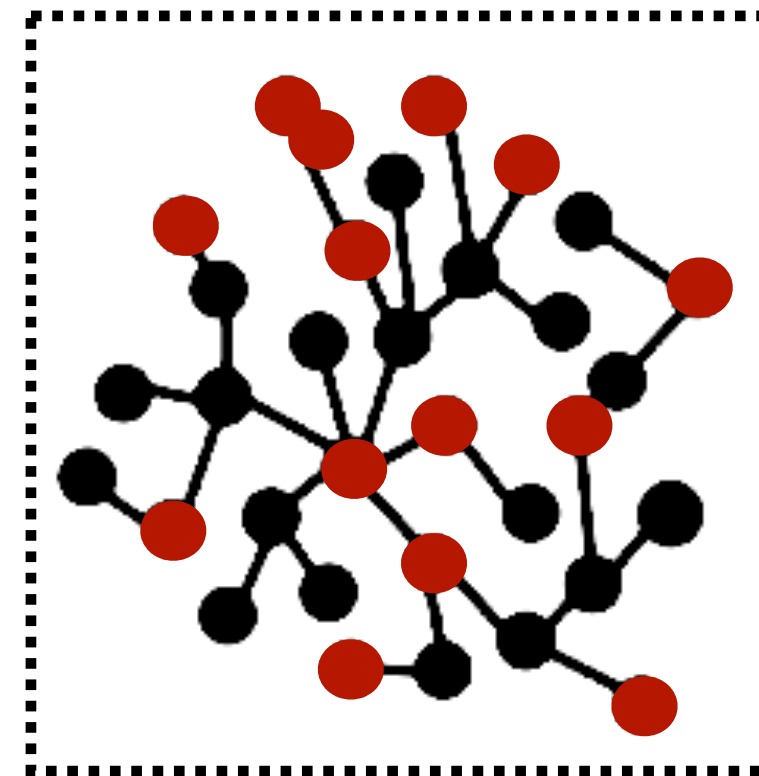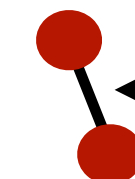*https://github.com/yymao/FoFCatalogMatching*

Perfect match

1-1 system

Unrecognized blend

2-1 system
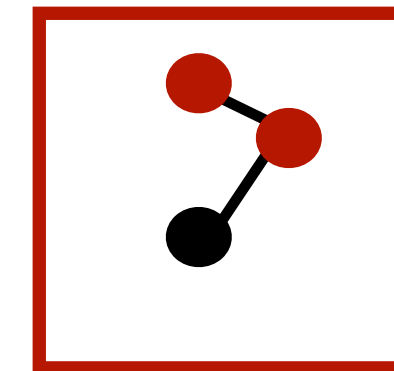
Recognized blend

2-2 system

n-m system

n = # of **galaxies** from **cosmoDC2**
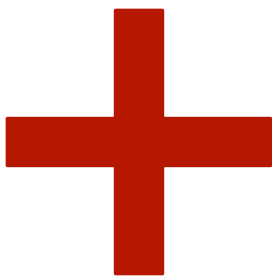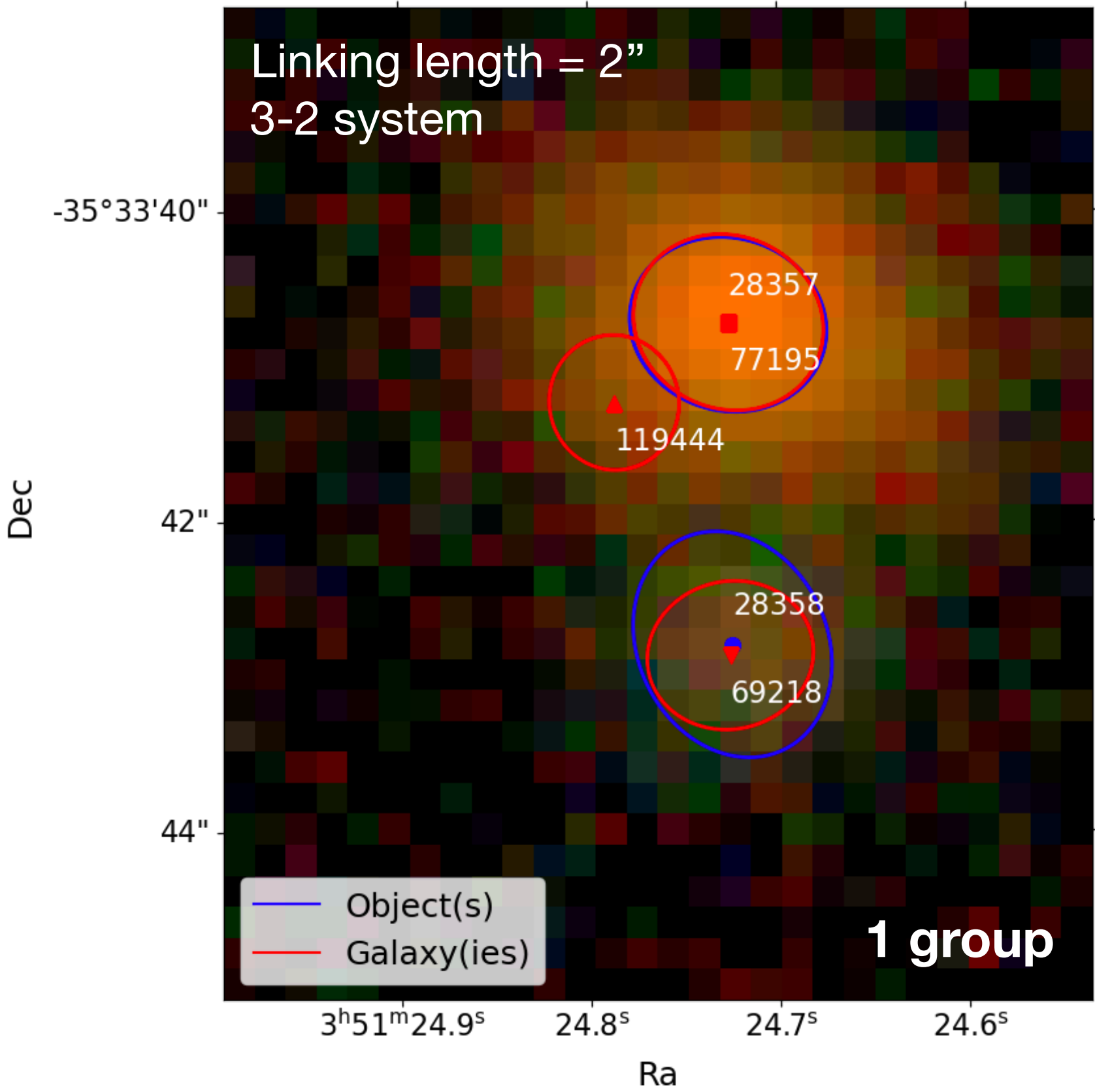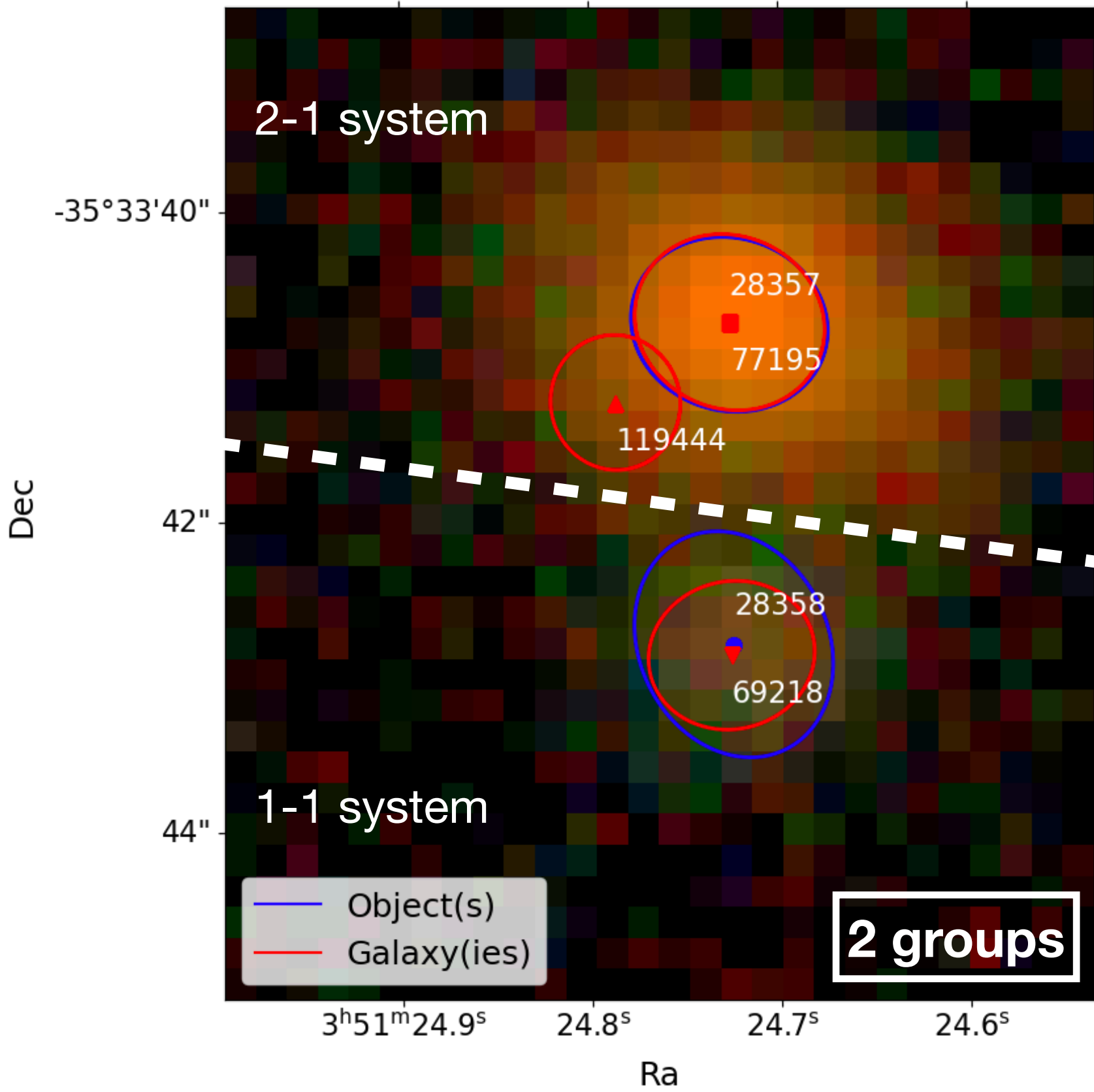m = # of **objects** from **DC2object**

Linking length

New matching algorithm: friendly

Friends-of-Friends = **distances** information

Overlap test = **shapes** information

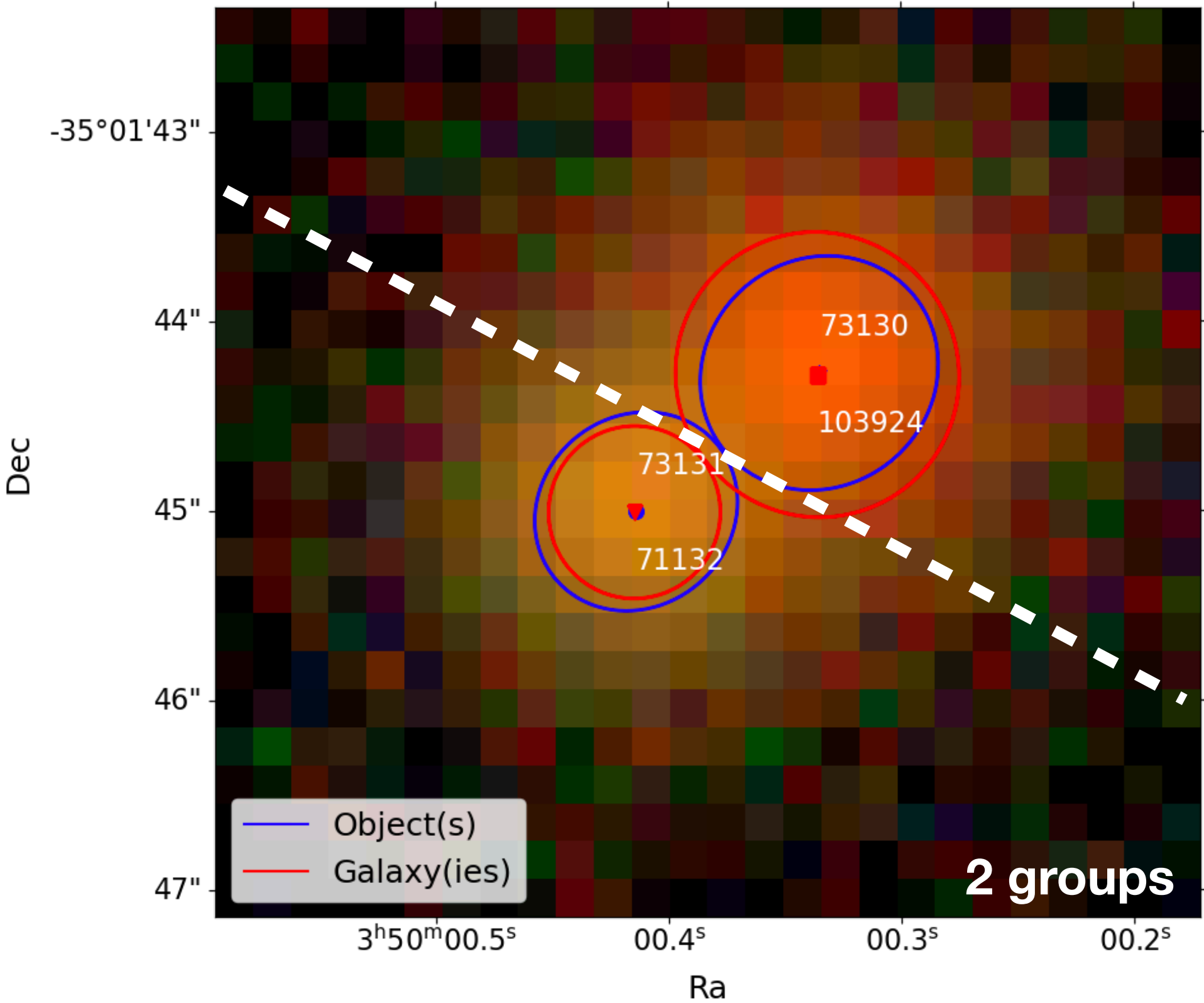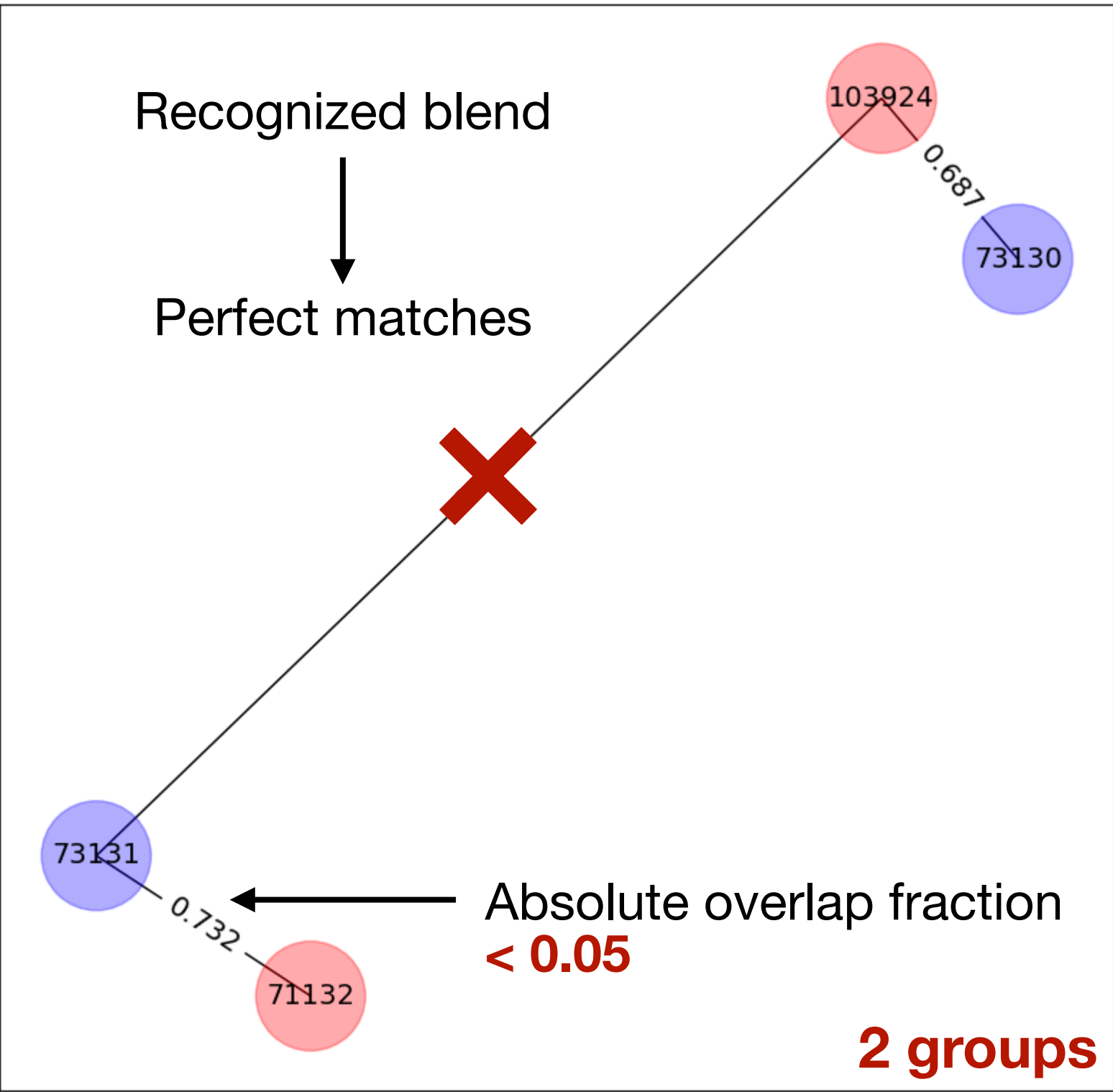**Friendly** = more robust matching algorithm

New matching algorithm: friendly
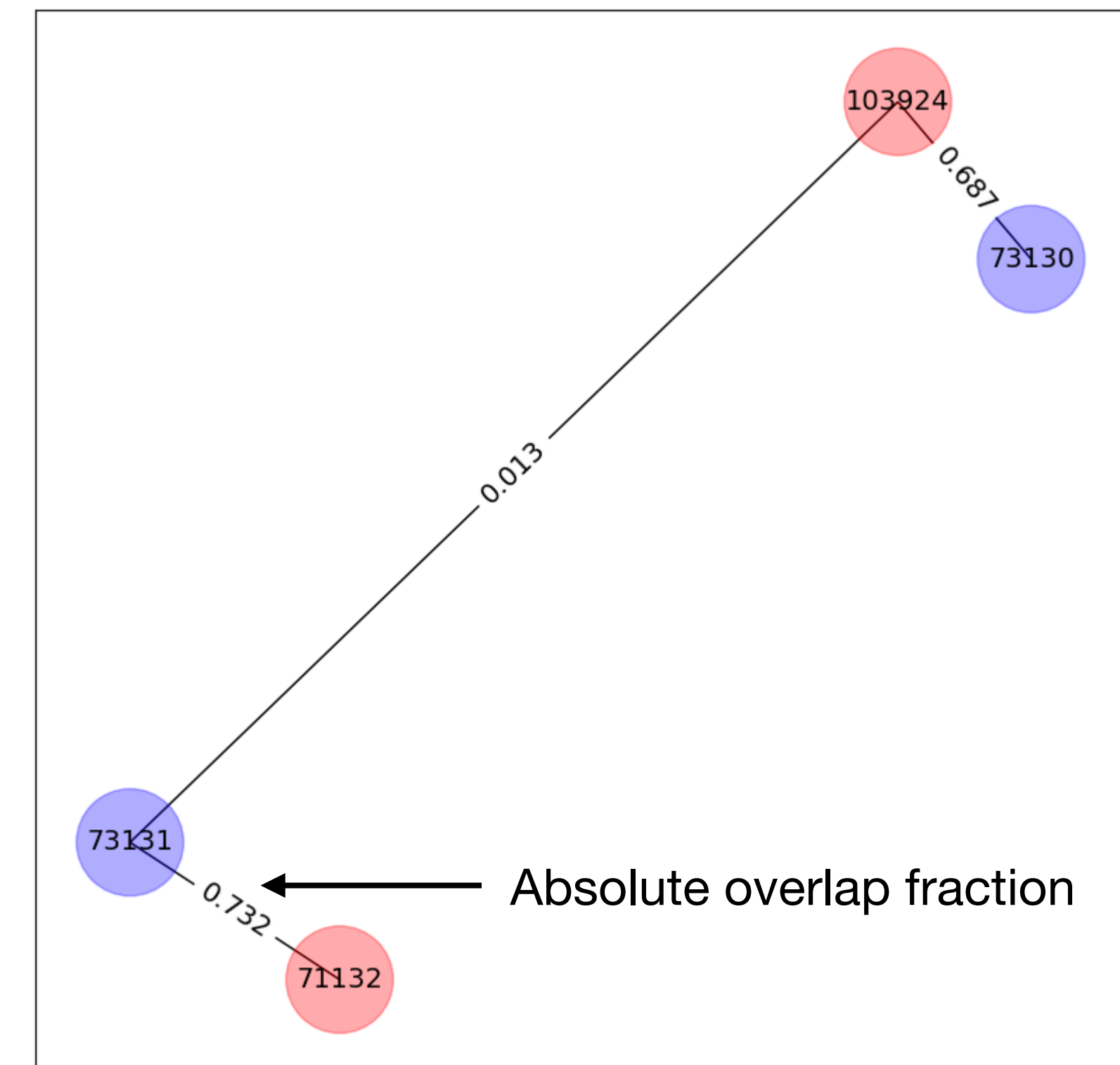

Friendly group

NetworkX graph

New matching algorithm: friendly

NetworkX graph

Next steps: Add metrics on the nodes/edges

- Absolute overlap fraction

- Purity

- Magnitudes/colors

- …

Absolute overlap fraction

Friendly = useful graph structure to better define the (un)recognized blends

Impact of blending on $\Delta\Sigma$ profiles

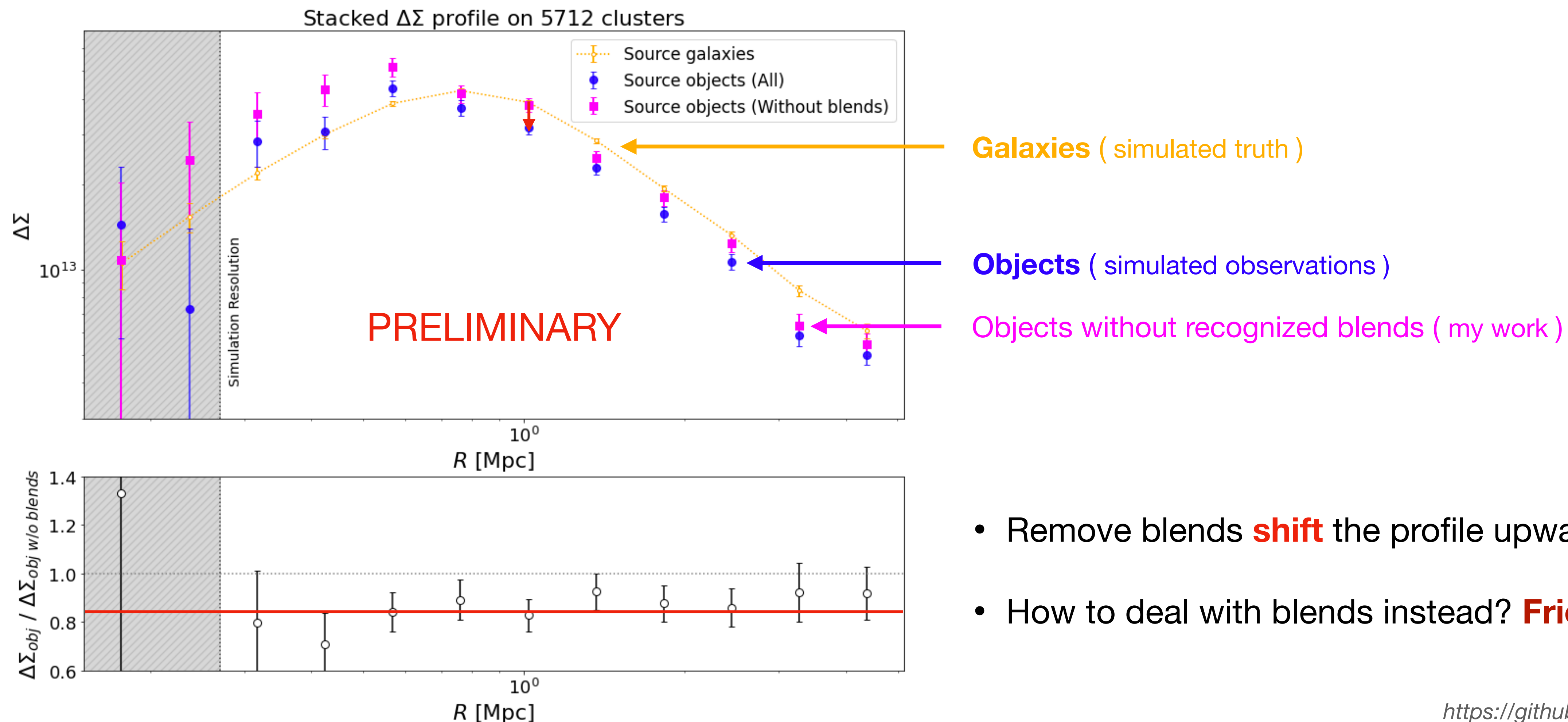# Impact of blending on $\Delta\Sigma$ profiles

% of unrecognized blended sources: ~9 %
% of recognized blended sources: ~30 %

Objective: study the impact of (un)recognized blends on $\Delta\Sigma$ profiles
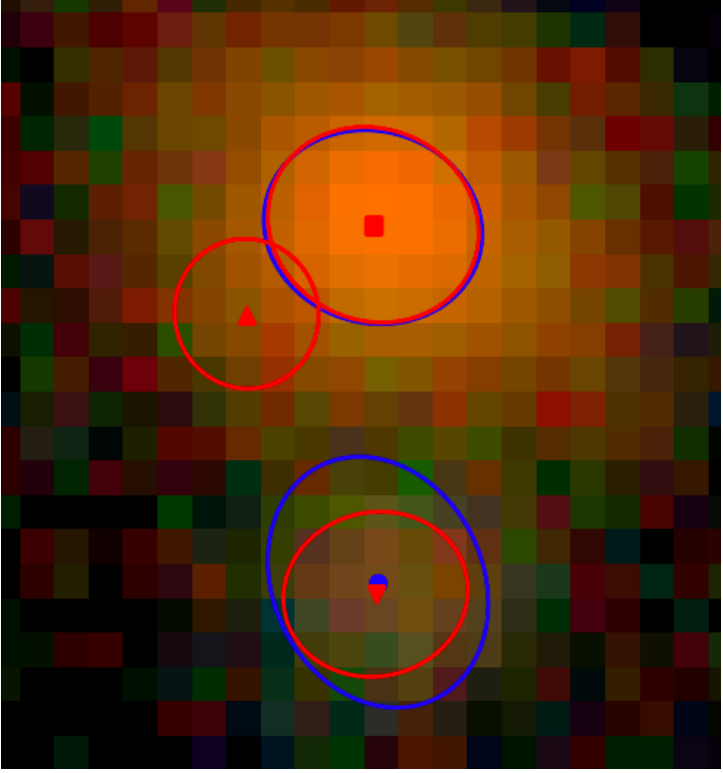
$$\Delta\Sigma(R, z_l) = \langle \Sigma_{crit}(z_{gal}, z_l) \ \epsilon_+^{obs} \rangle$$

Stacked ΔΣ profile on 5712 clusters

Galaxies (simulated truth)

Objects (simulated observations)

Objects without recognized blends (my work)

- Remove blends **shift** the profile upwards by **20%**

- How to deal with blends instead? **Friendly**

https://github.com/LSSTDESC/CLMM

Development of friendly
= new blending matching algorithm

Better definition of (un)recognized
blends
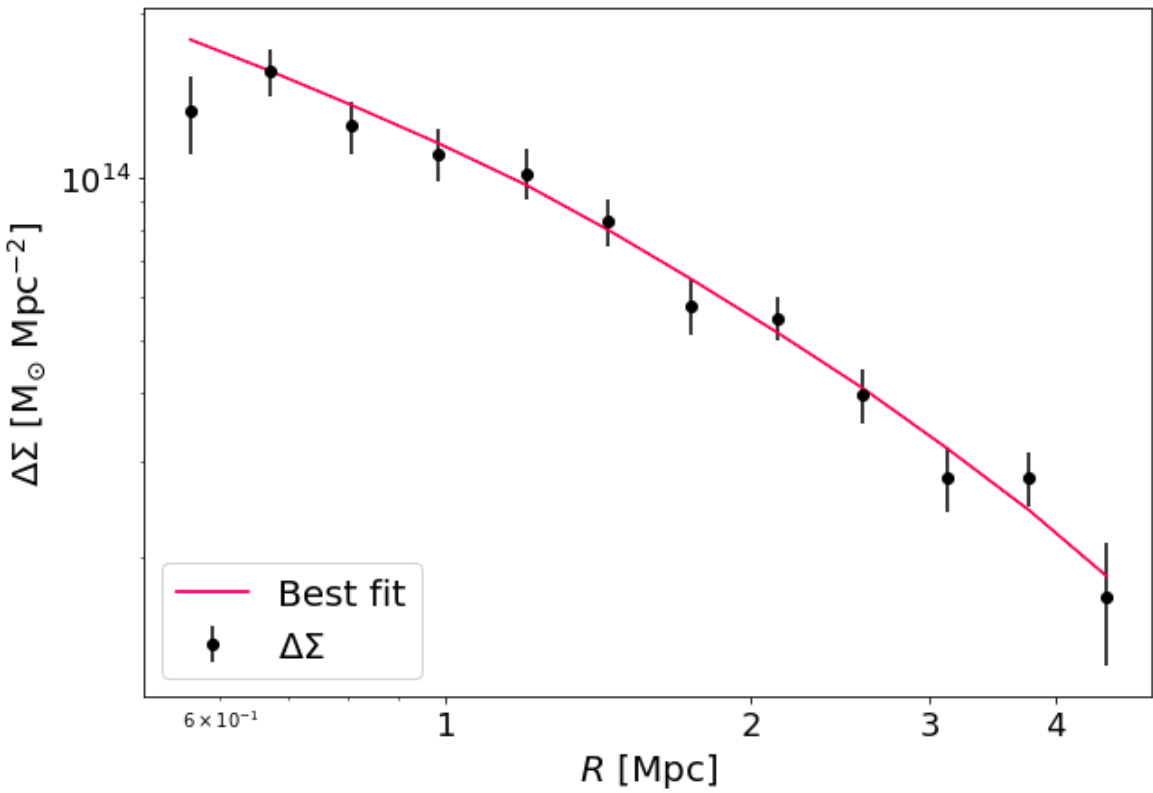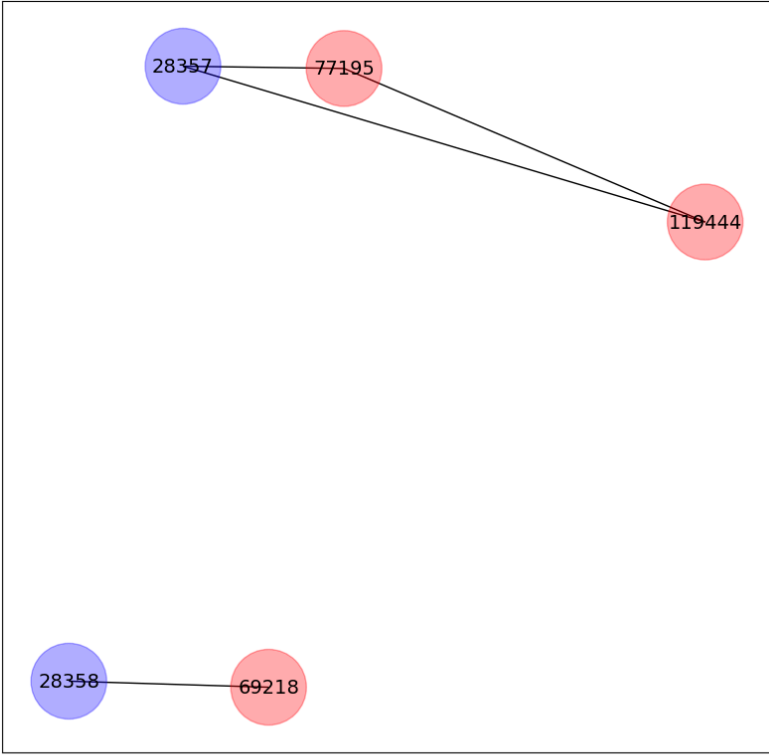
Impact of blending on
$\Delta\Sigma$ **profiles**

Impact on galaxy clusters mass
estimates and on cosmology

Thank you for your attention !