Blending impact on galaxy clusters with Rubin/LSST

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Galaxy clusters

Millennium 2005, Springel et al.

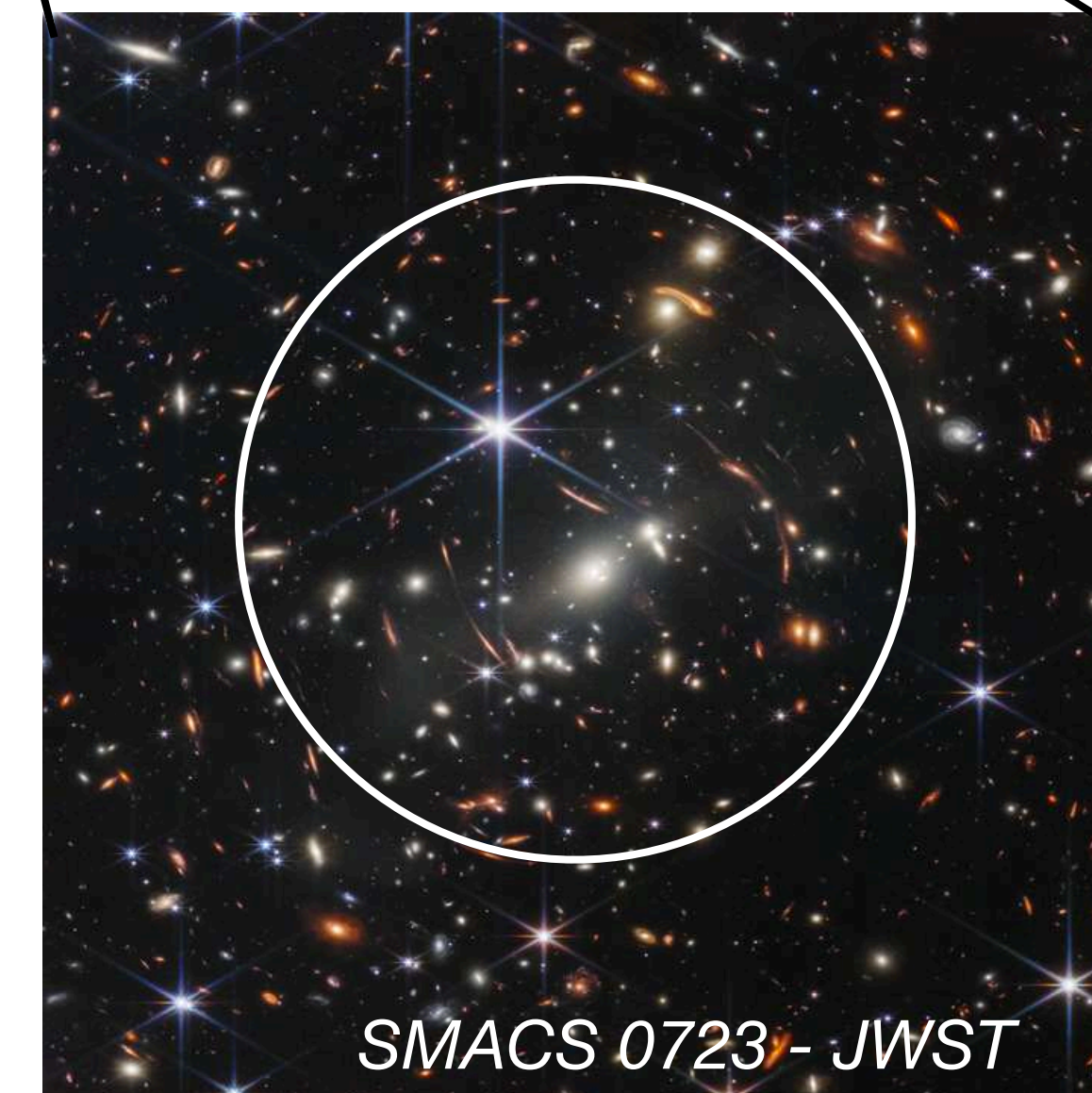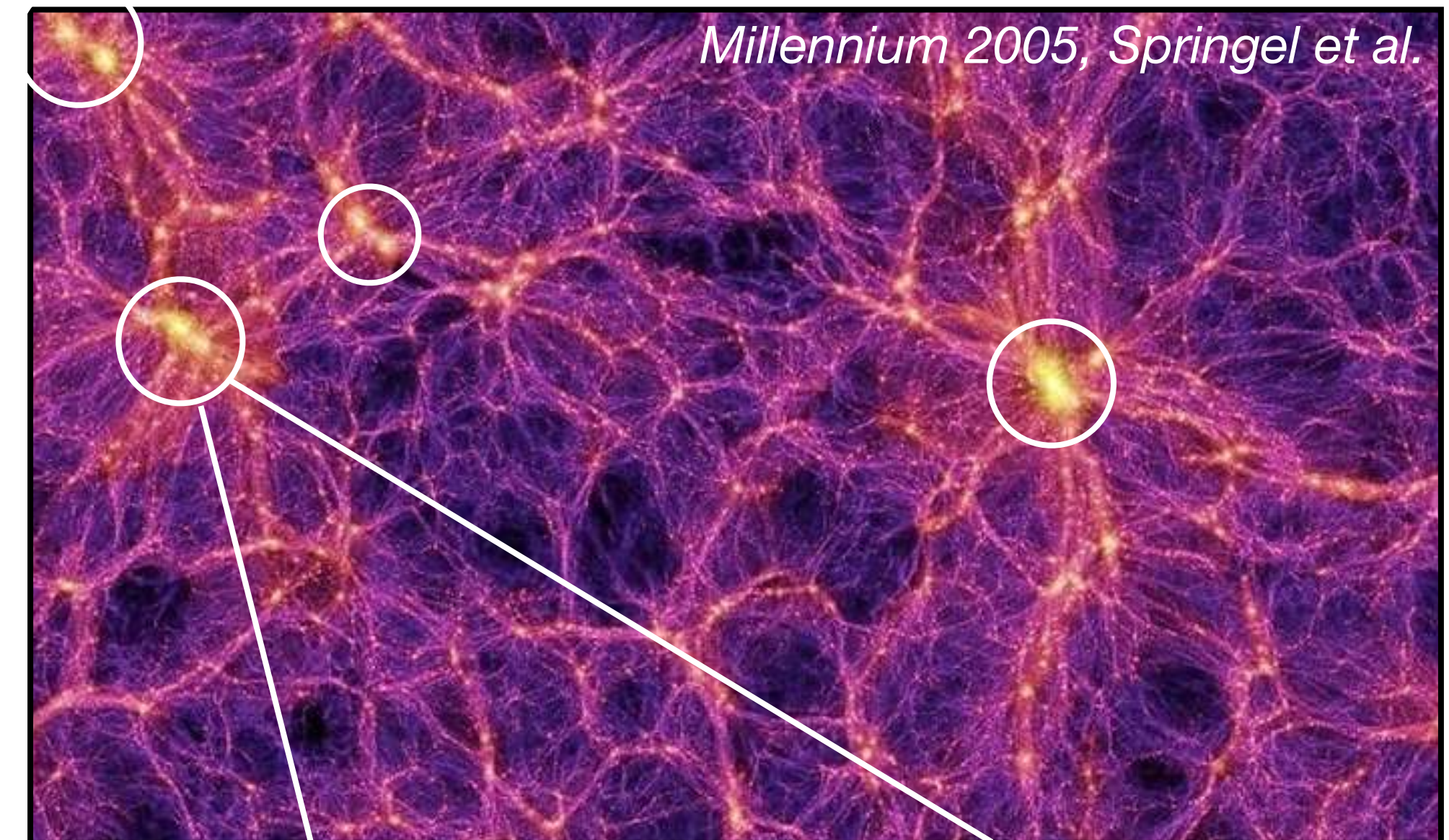**Largest** gravitationally bound structures in the Universe

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

Tracers of the matter over-densities

- Abundance depends on cosmology

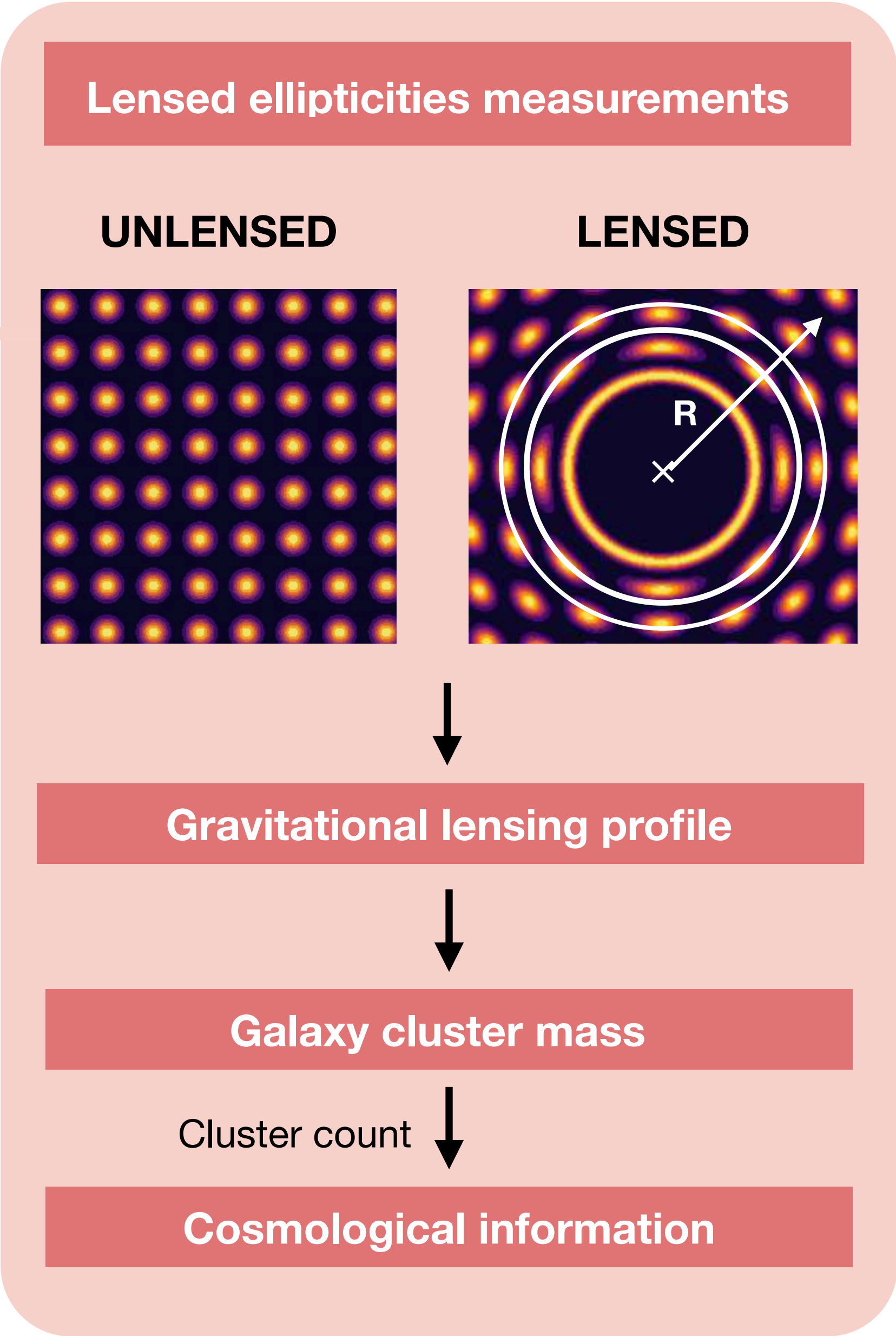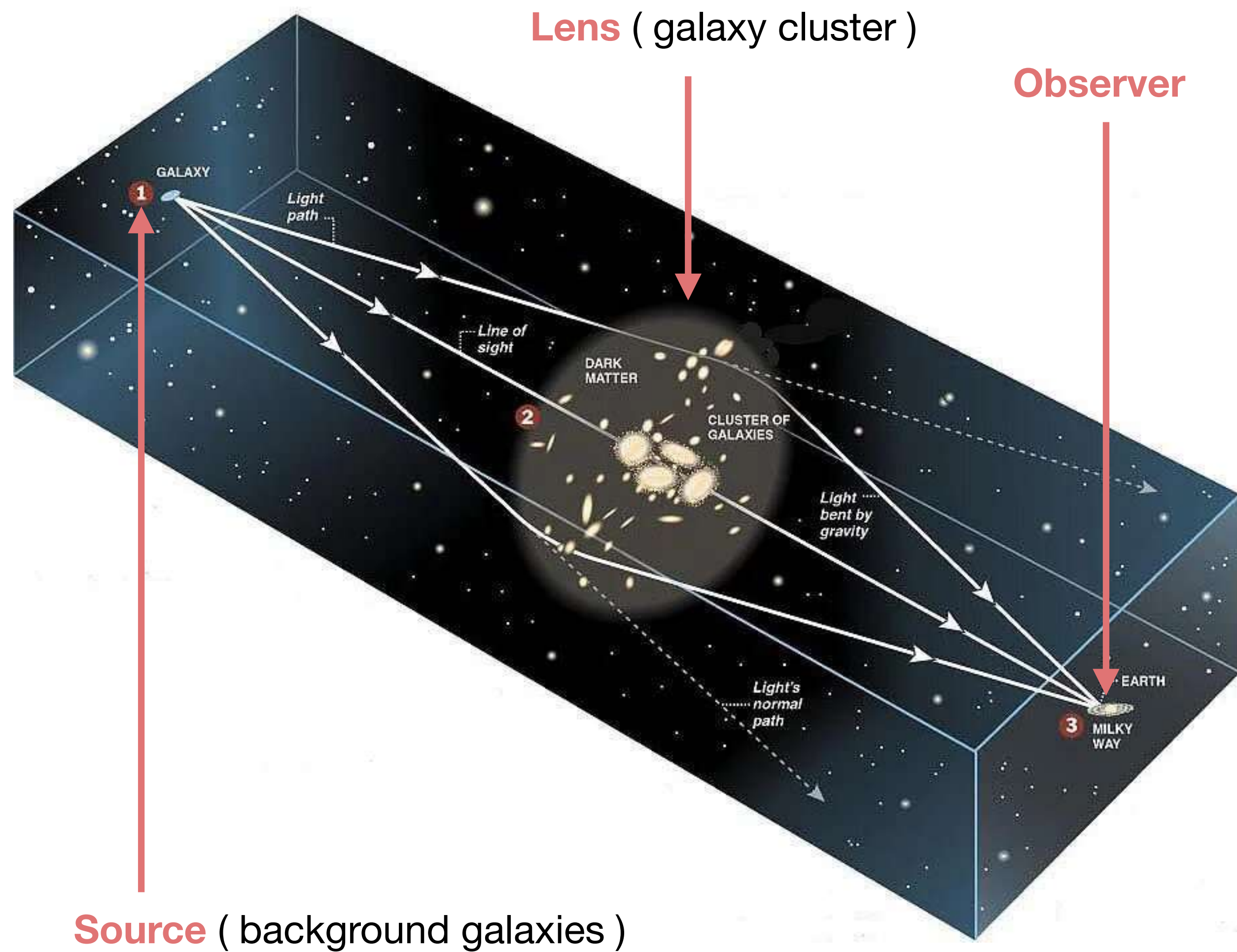**Studied through their counting per bins of mass and redshift**

Indirect measurements of cluster masses through weak gravitational lensing
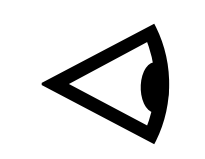

SMACS 0723 - JWST

Weak gravitational lensing

Lens (galaxy cluster)

Observer

Source (background galaxies)

Lensed ellipticities measurements

UNLENSED   LENSED

R

Gravitational lensing profile

Galaxy cluster mass

Cluster count

Cosmological information

Weak gravitational lensing

Lens (galaxy cluster)
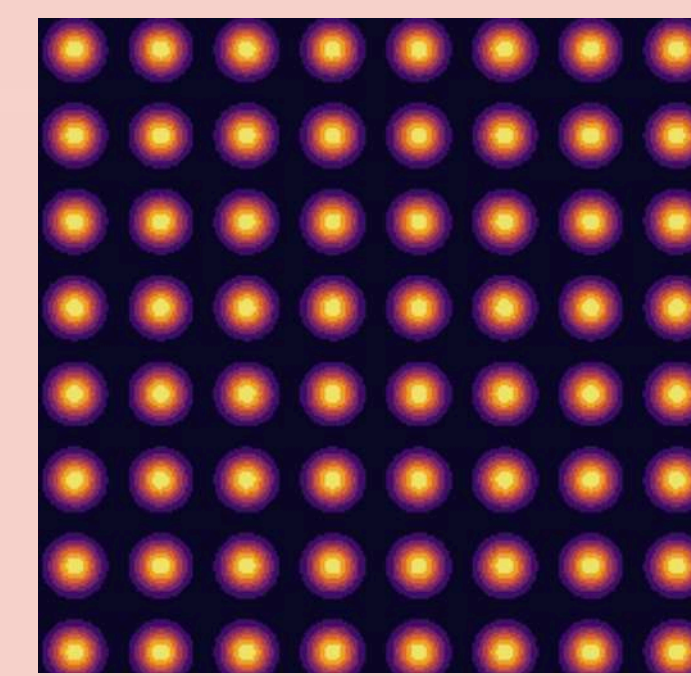
Observer

Source (background galaxies)
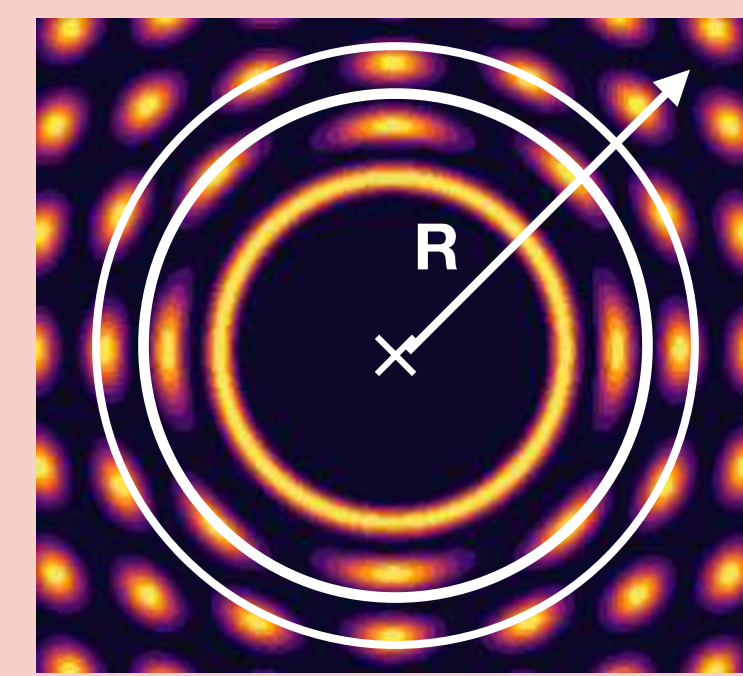
Need for a large number of data
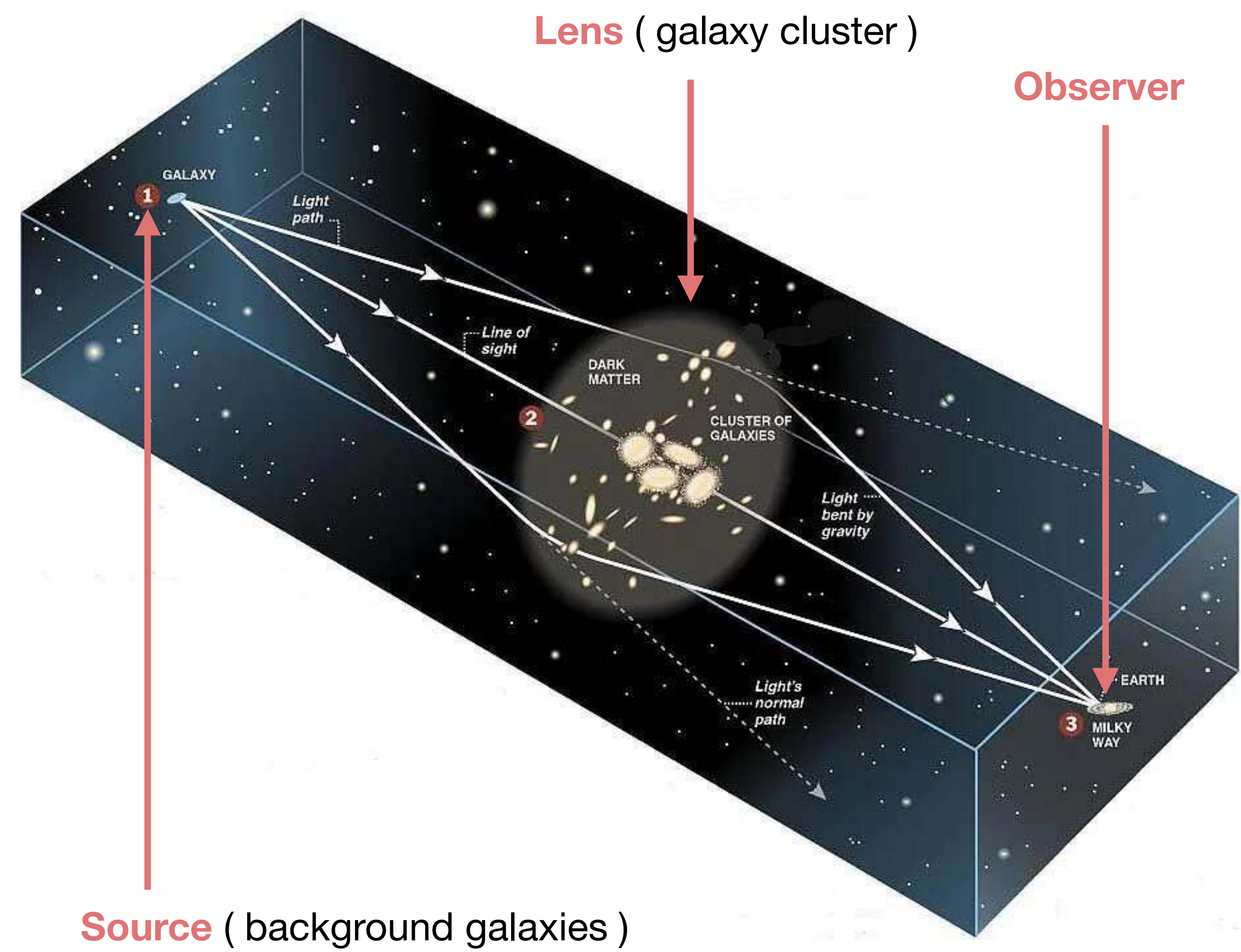
Rubin/LSST

Lensed ellipticities measurements

UNLENSED

LENSED

R

Gravitational lensing profile

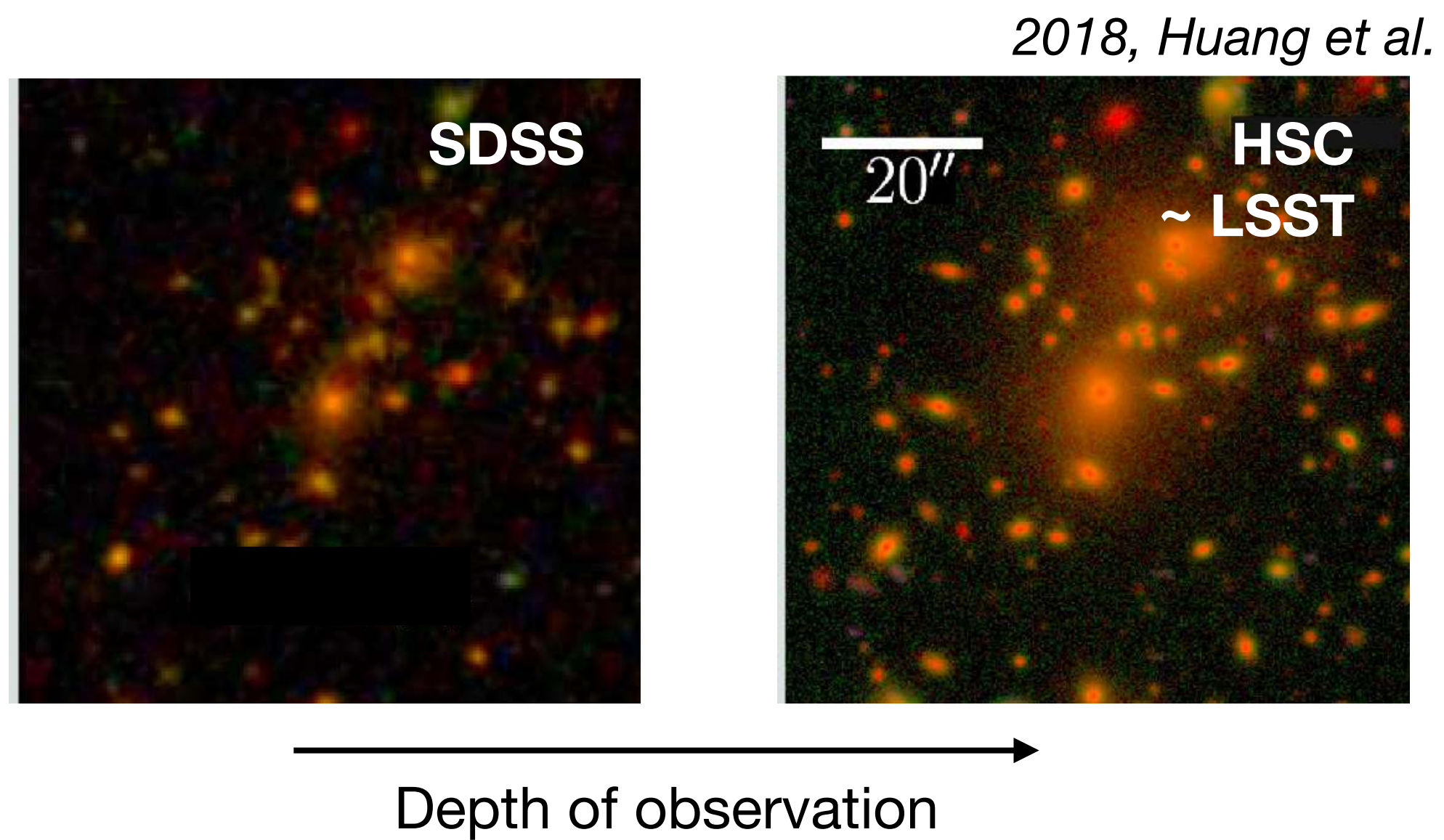Galaxy cluster mass

Cluster count

Cosmological information

Blending

Superposition of galaxies on the images due to:

- the **depth** of observation
- the **atmosphere**

2018, Huang et al.

SDSS

20″ HSC ~ LSST

Depth of observation

Blending increases with **depth of observation**
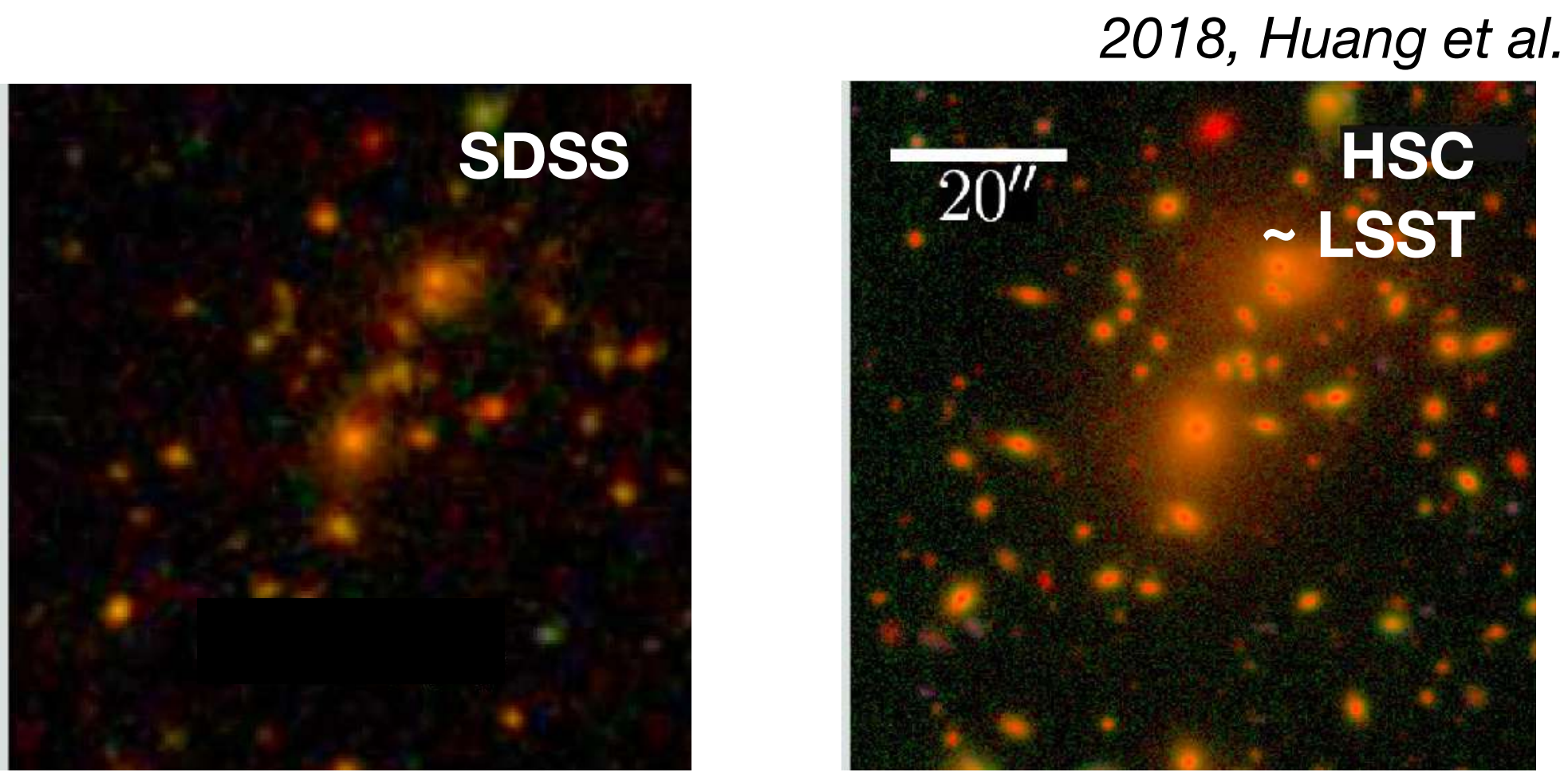
Blending

Superposition of galaxies on the images due to:

- the **depth** of observation
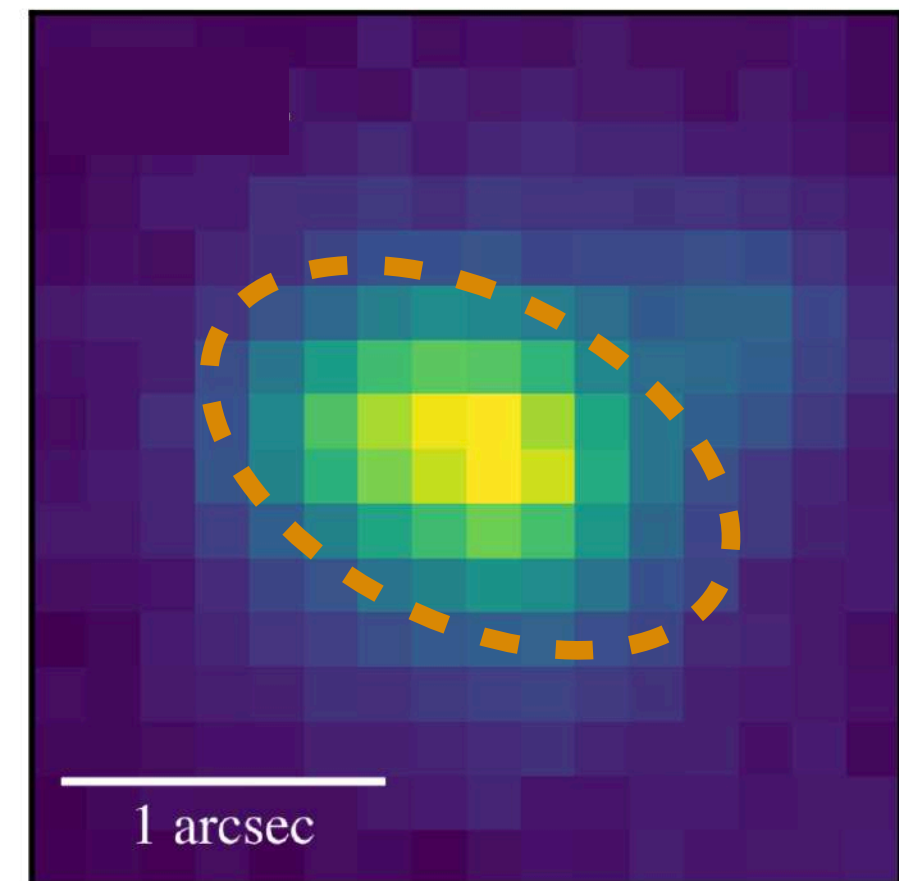- the **atmosphere**
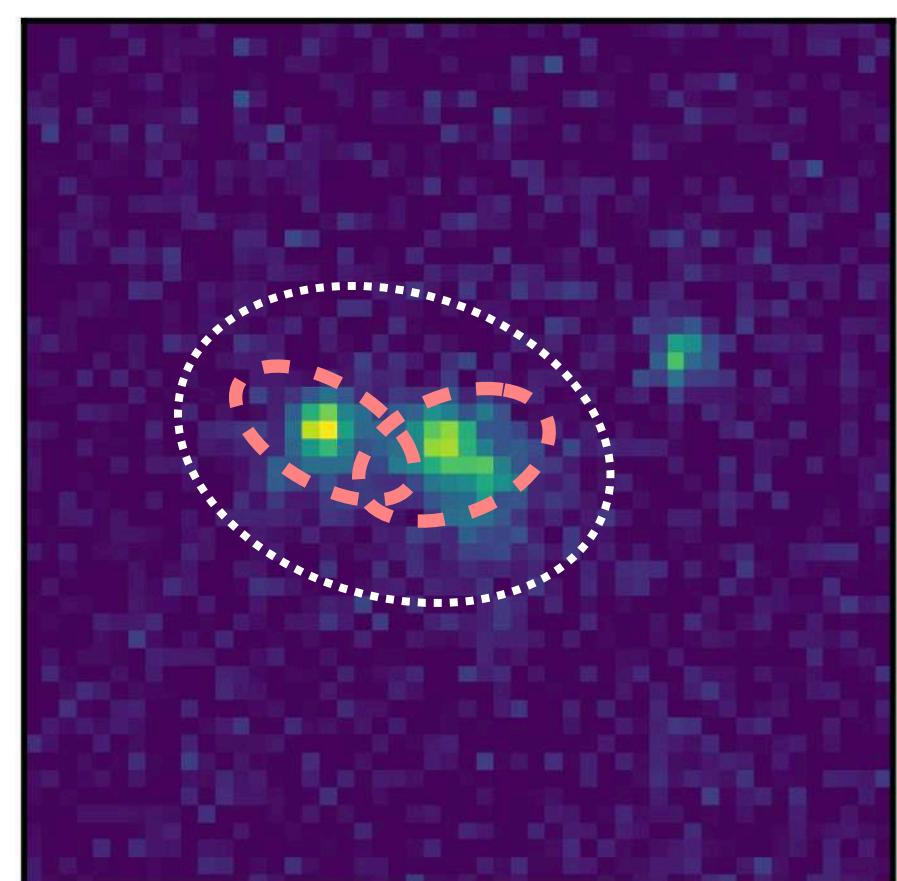
2018, Huang et al.

SDSS

20″ HSC
~ LSST

Depth of observation

Blending increases with **depth of observation**

Unrecognized blends
~14 - 20 %*

Subaru/HSC

Recognized blends
~40 %

Hubble/ACS

1 arcsec

2021, Shibuya et al.

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

Blending will impact future Rubin/LSST weak lensing data
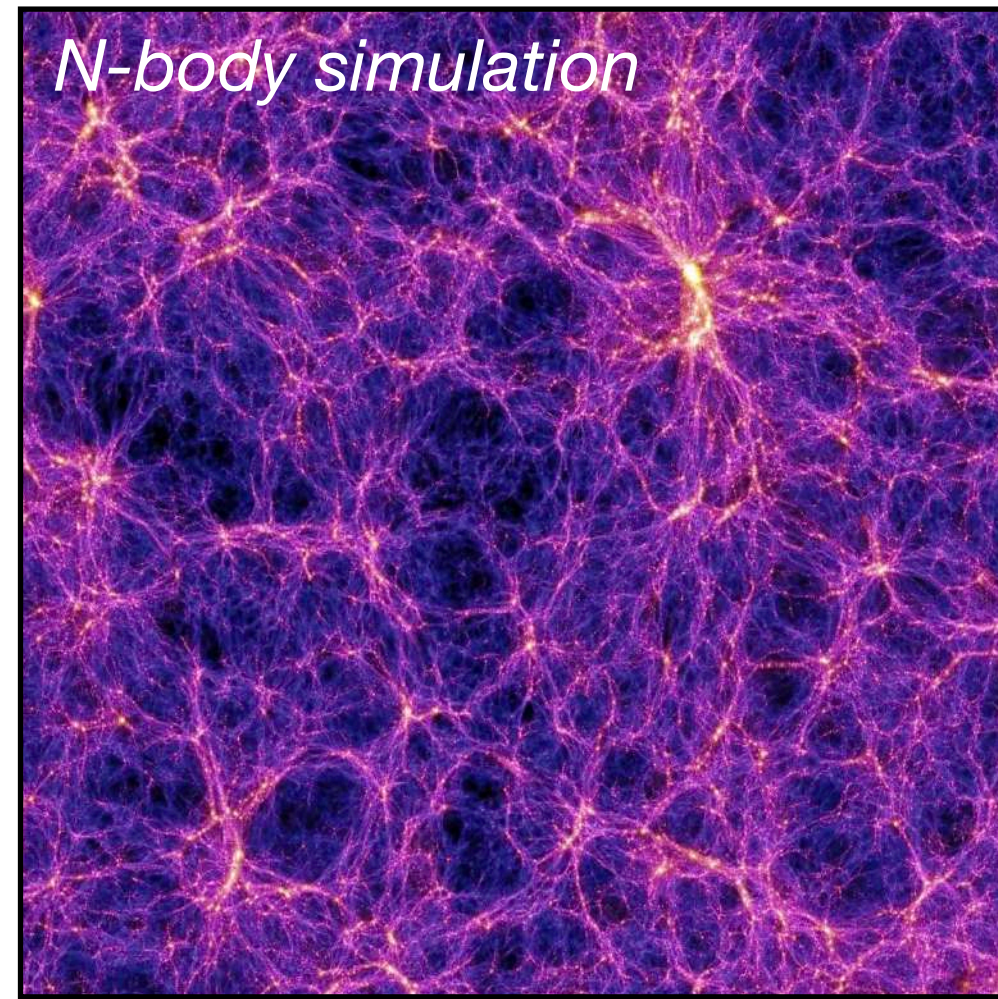
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Simulated catalogs

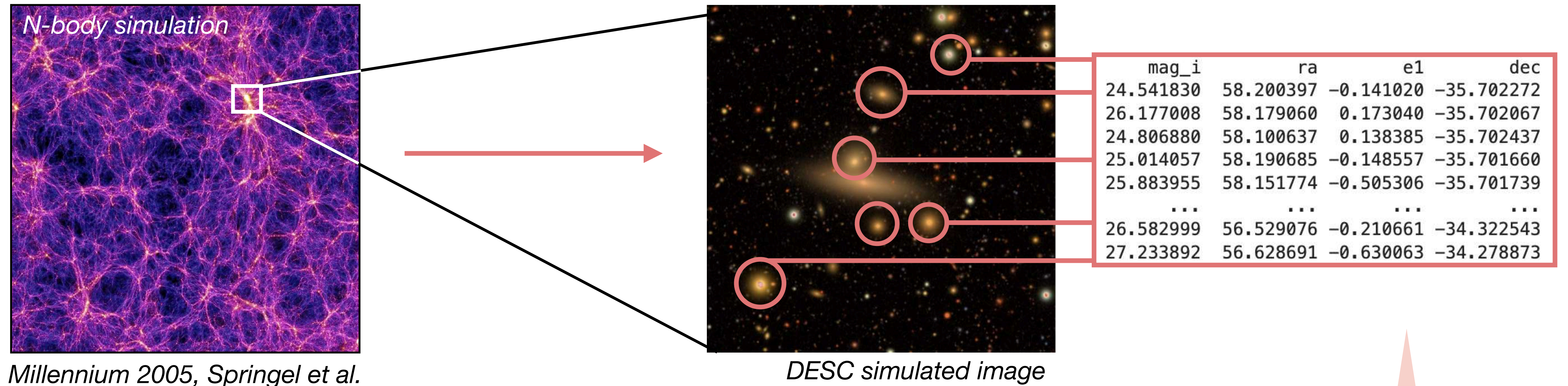*N-body simulation*

Millennium 2005, Springel et al.

cosmoDC2 = truth catalog

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

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

- mag < 30, z = 3

Simulated catalogs

N-body simulation

Millennium 2005, Springel et al.

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

DESC simulated image

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

- Images simulated using cosmoDC2

- Detection of **objects**
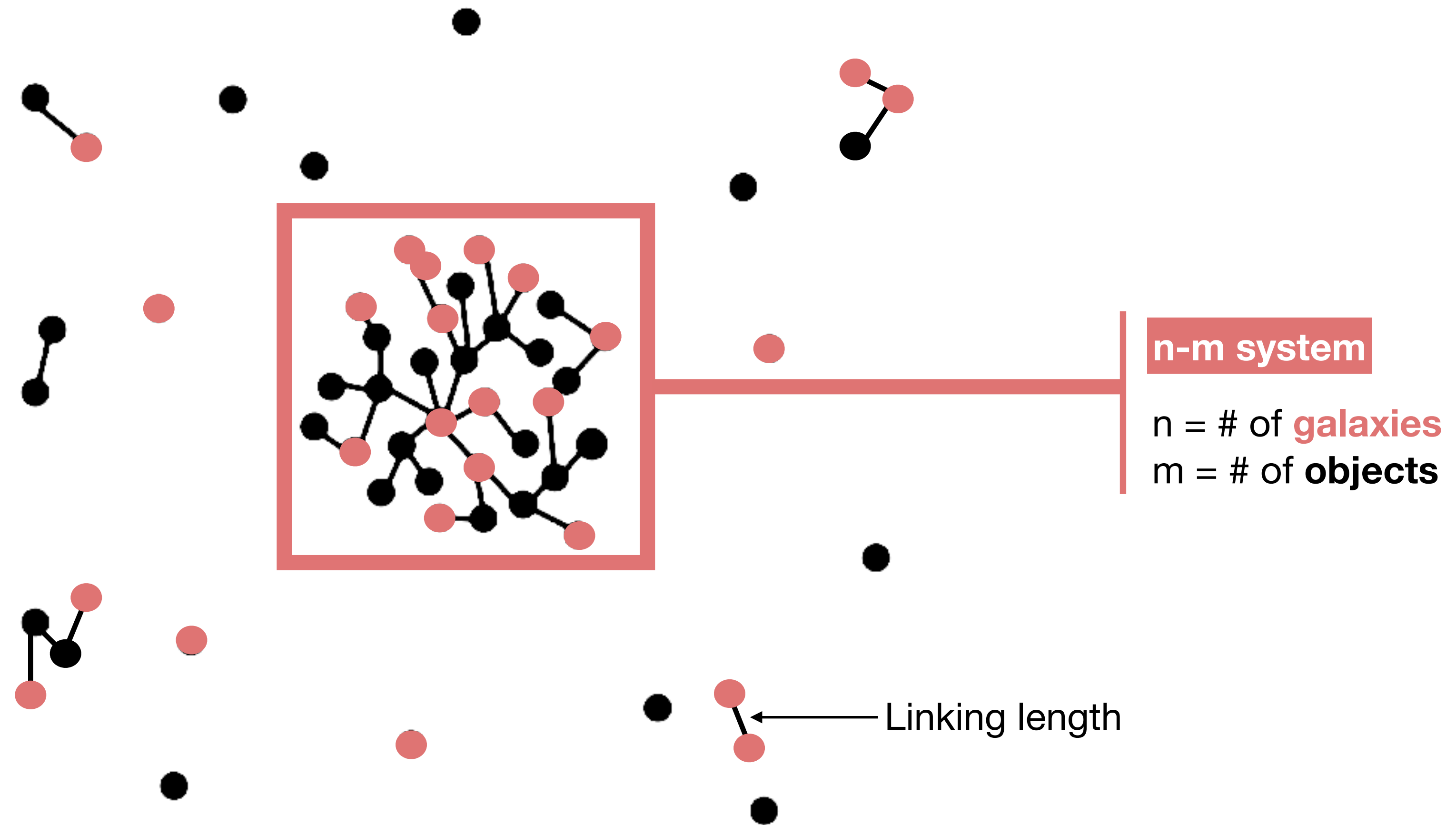
- Measured positions, magnitudes (< 28), shapes…

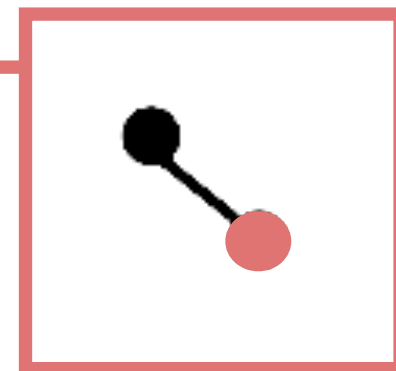Identification of blends through catalogue **comparison**

Friends-of-Friends

https://github.com/yymao/FoFCatalogMatching

n-m system

n = # of **galaxies**
m = # of **objects**

Linking length

Friends-of-Friends

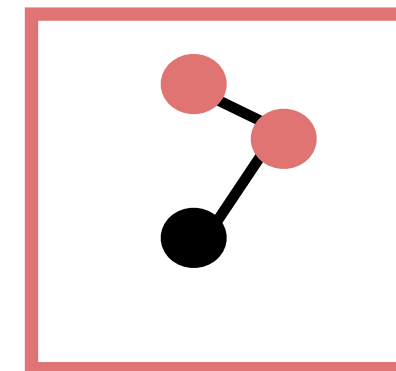*https://github.com/yymao/FoFCatalogMatching*

Perfect match
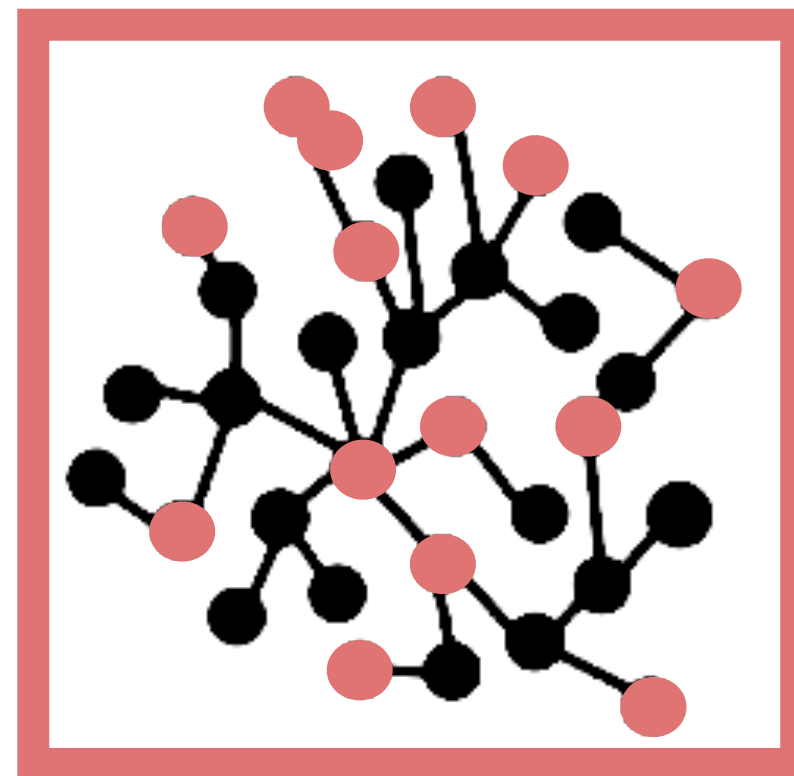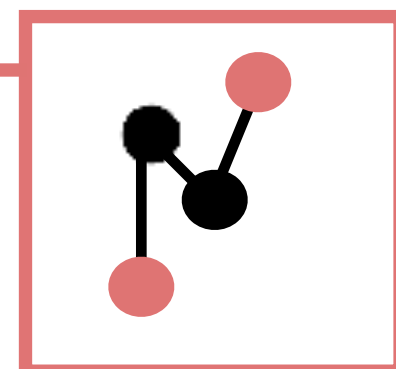
1-1 system

Unrecognized blend

2-1 system
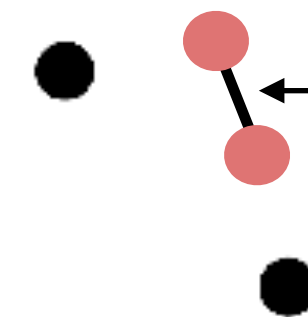
n-m system

n = # of **galaxies**
m = # of **objects**

Recognized blend

2-2 system

Linking length = **0.4"**

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Regions of high densities

OUTSIDE

INSIDE

HST

Abell 1689, HST
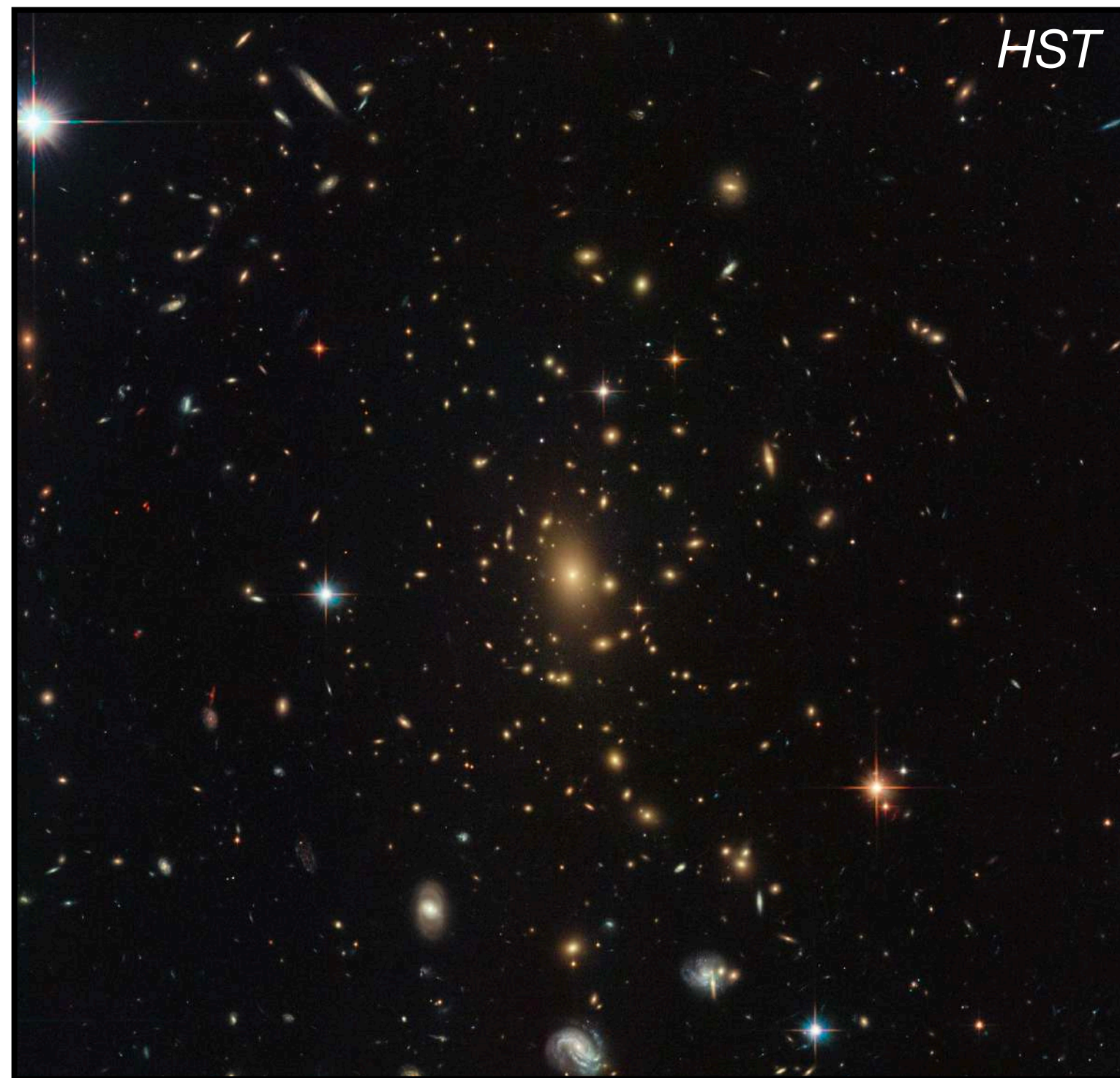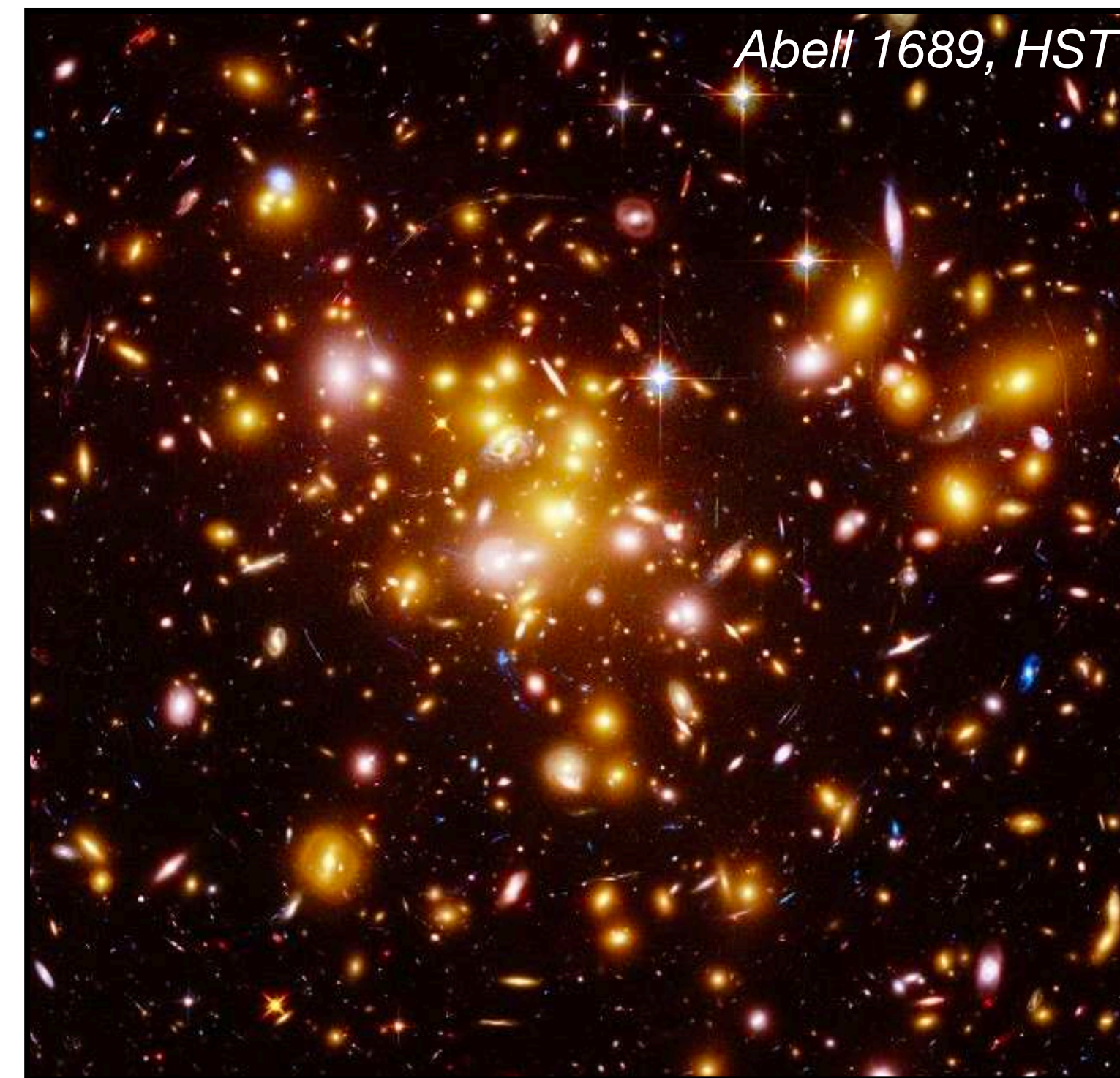
Galaxy clusters = high density regions = blending

Massive dark matter haloes

Millennium 2005, Springel et al.
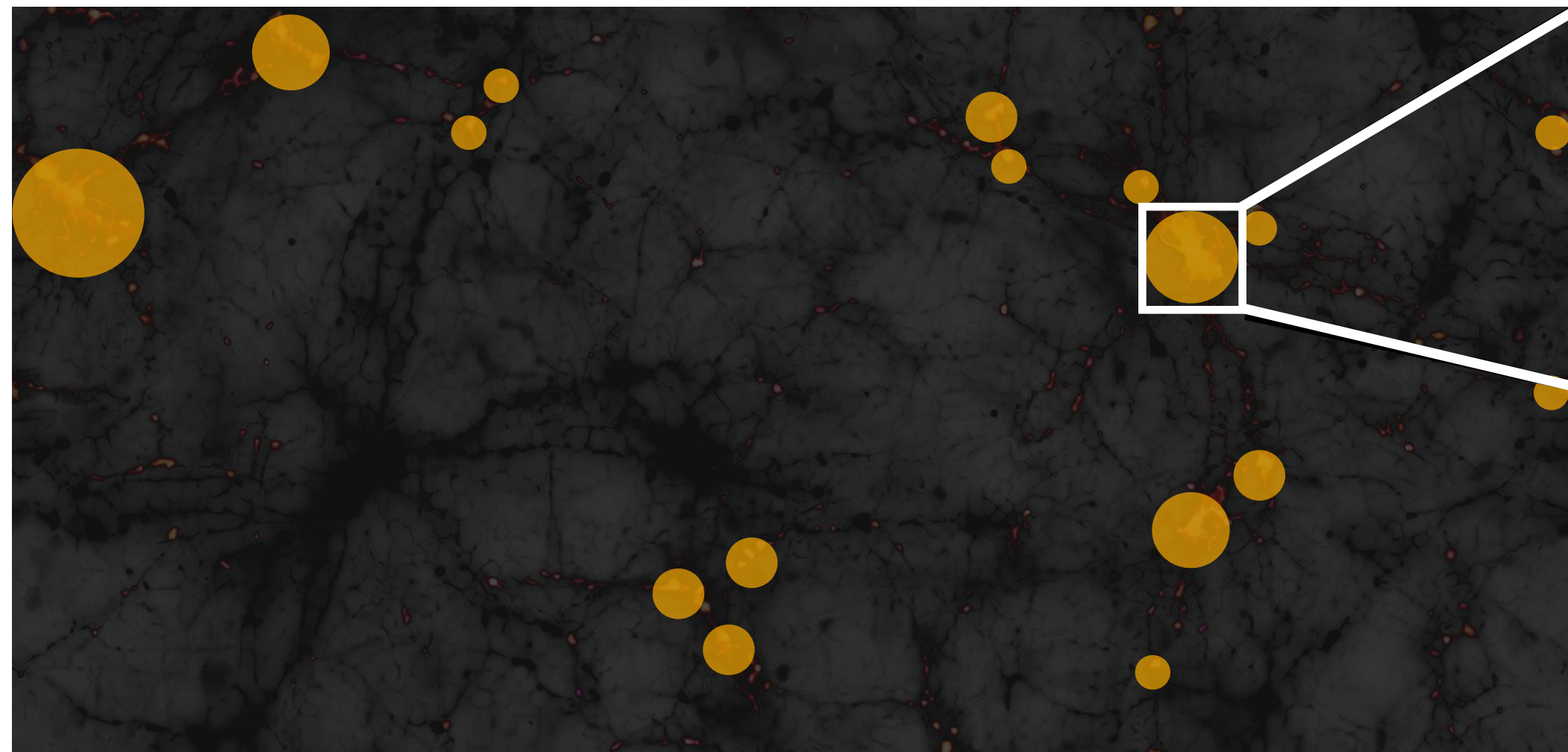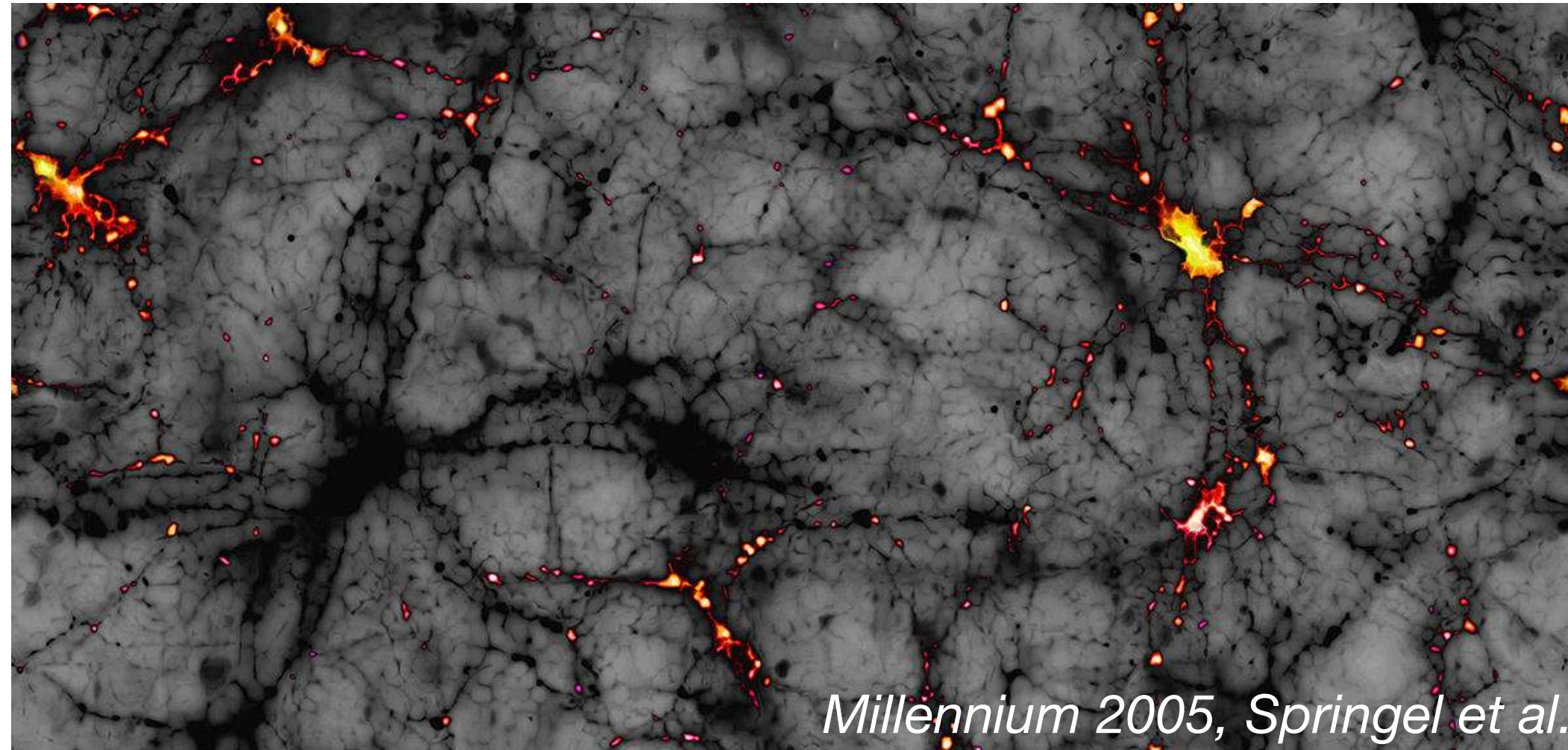
Galaxy clusters are difficult to detect → use of DC2 dark matter **haloes**

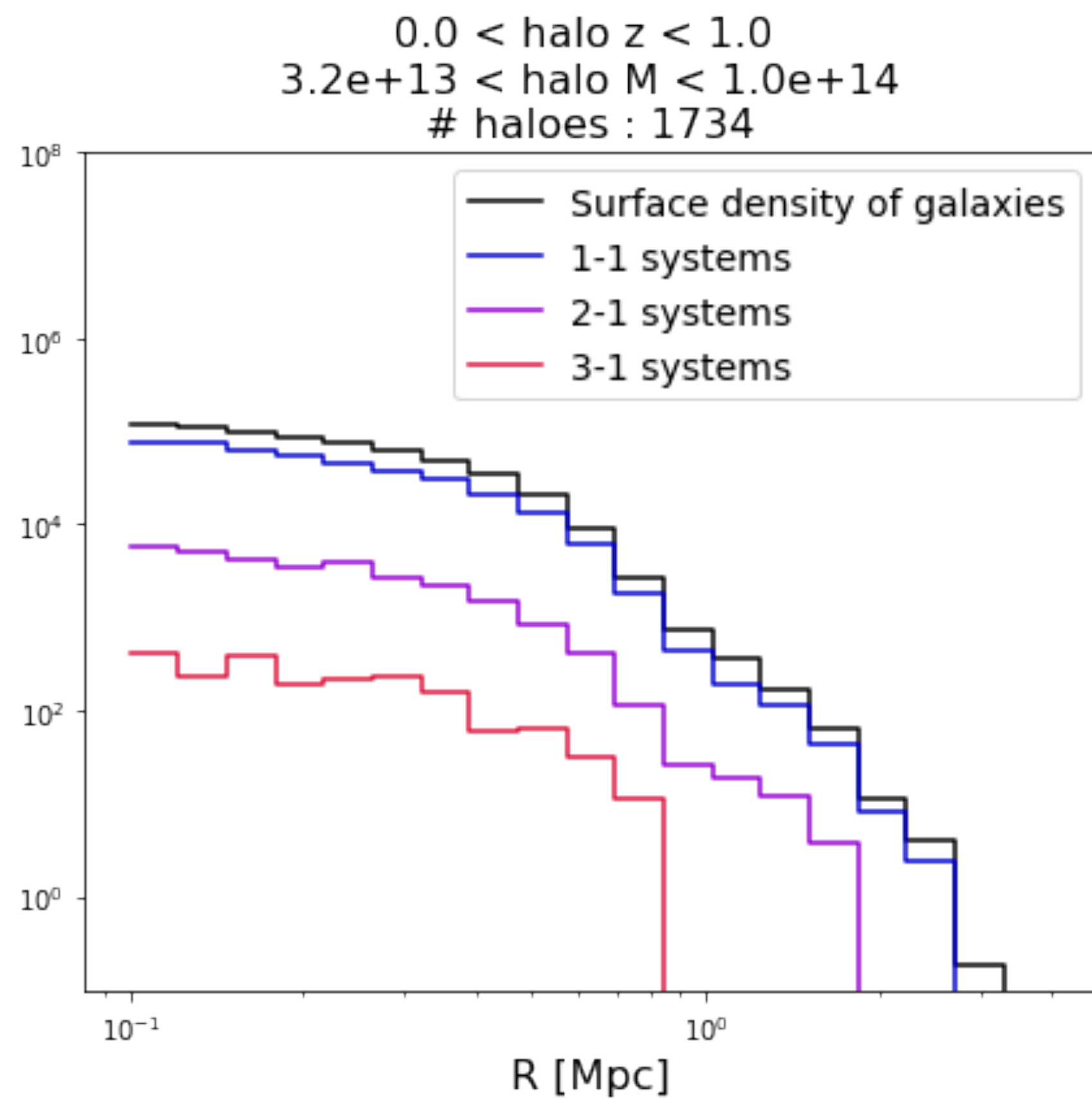Detected object

R
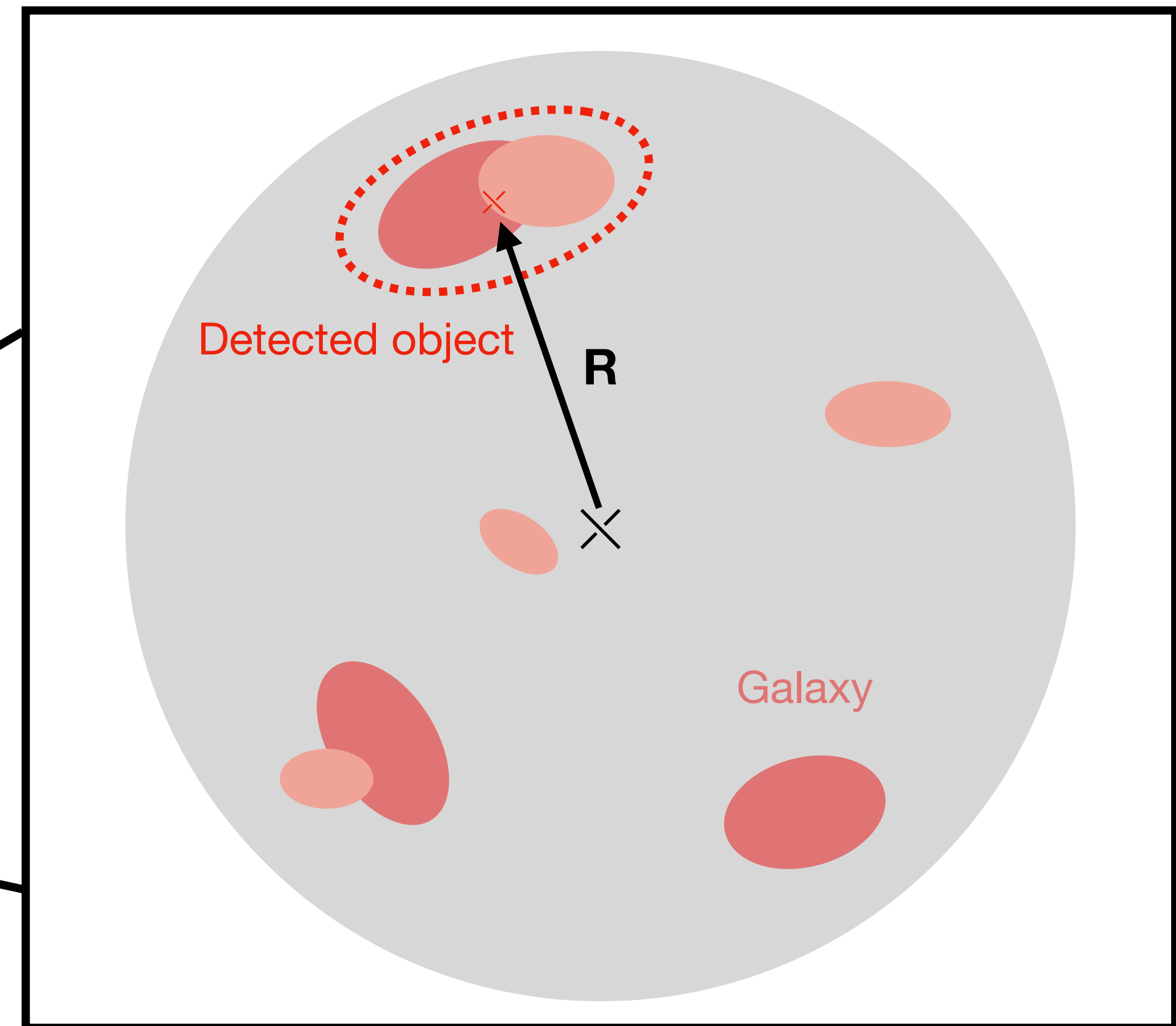
Galaxy

Blended systems demography

Surface densities of blended systems in haloes

- Halo of the group = halo of the brightest galaxy

- Look at systems in haloes of mass $M > 10^{13.5} M_\odot$

- Proportion of unrecognized blends in massive haloes: $\sim 8\,\%$

- Higher density of blended systems near the halo centres

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Cosmic shear and lensing profiles

- **CLMM** = developed by **DESC collaboration**

Cosmic shear γ

Lensed ellipticities
$$\mathbf{e}^{\mathrm{obs}} = \mathbf{e}^{\mathrm{int}} + \gamma$$

Cosmic shear and lensing profiles
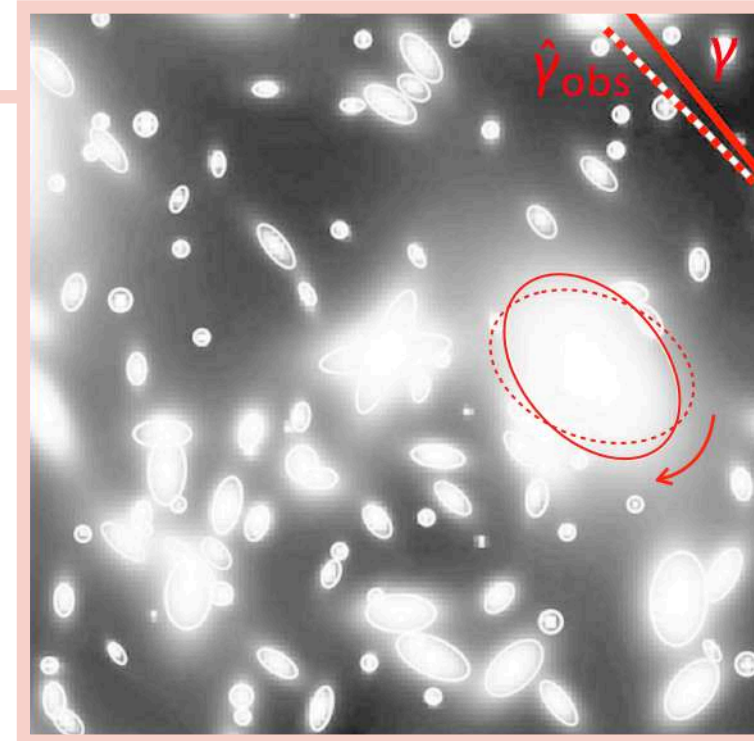
- **CLMM** = developed by **DESC collaboration**

Cosmic shear γ

Lensed ellipticities
$$\mathbf{e}^{\mathrm{obs}} = \mathbf{e}^{\mathrm{int}} + \gamma$$

Radial binning
$$\langle \mathbf{e}^{\mathrm{obs}} \rangle = \gamma$$

Tangential shear profile

Fitting a lens mass

Stacked tangential shear profiles

36 stacked haloes of mass $M > 10^{14}$

Uncalibrated

Source galaxies
Source objects

R [Mpc]

Impact of the unrecognized blends

Tangential shear profiles

Lens centre

All galaxies
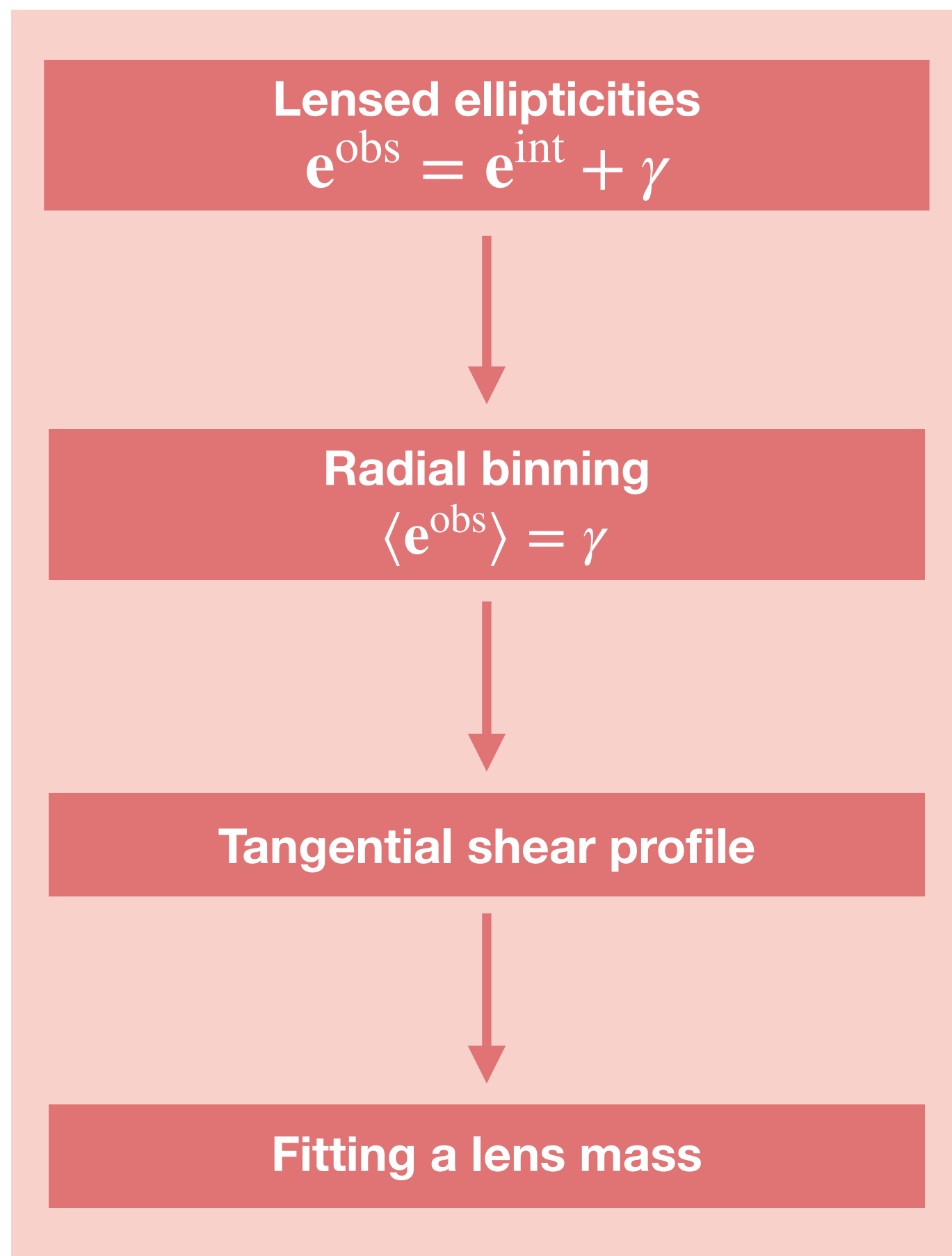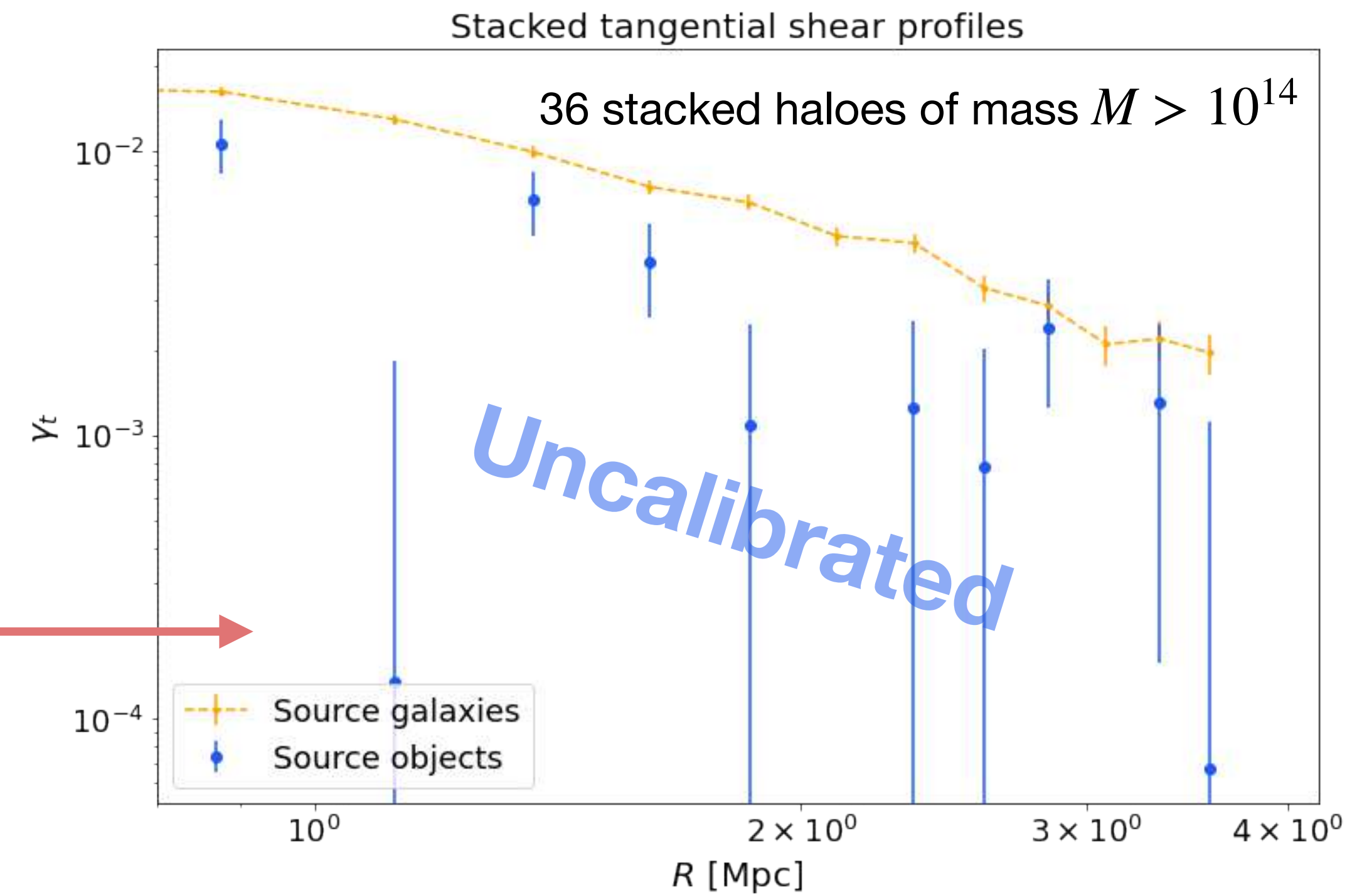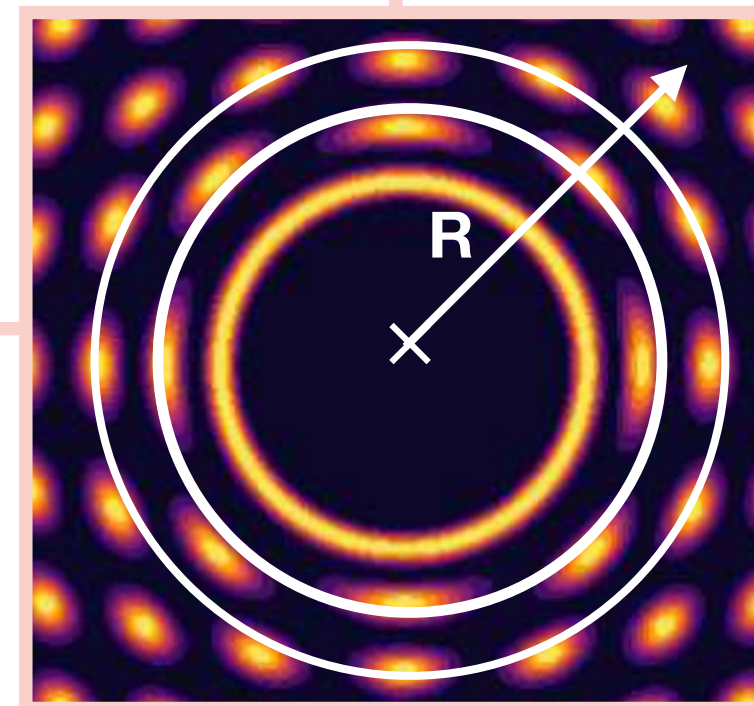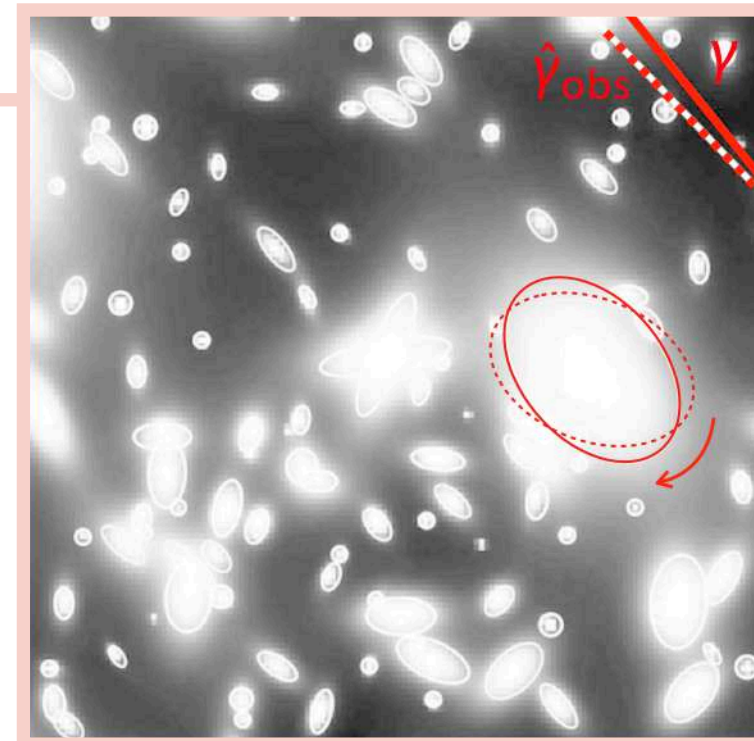
Unrecognized blends removed

bias

All objects
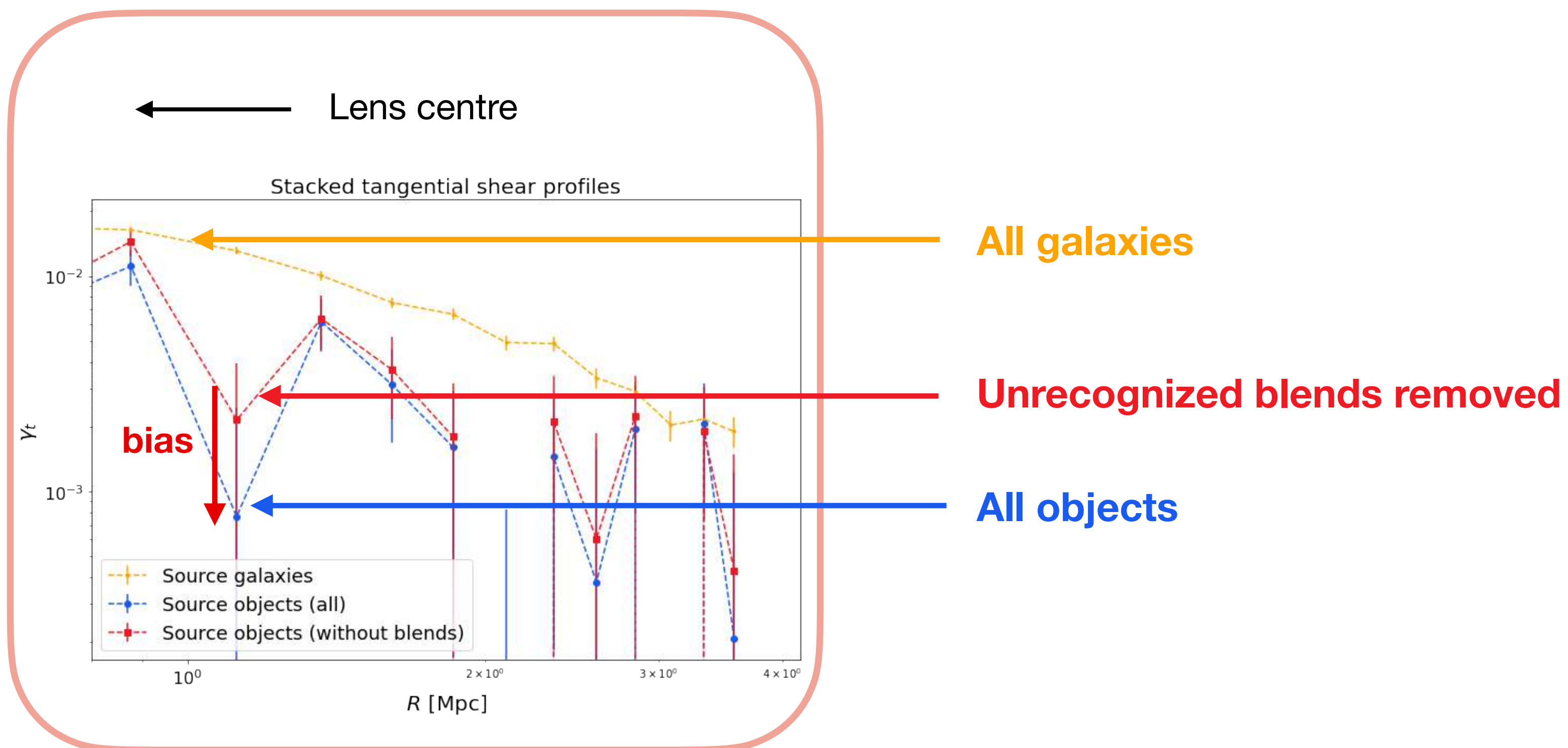
$$\text{Systematic bias} = \frac{\gamma_{t_{obj}}}{\gamma_{t_{without\,blends}}}$$

Impact of the unrecognized blends

Tangential shear profiles	Profiles fit

Lens centre
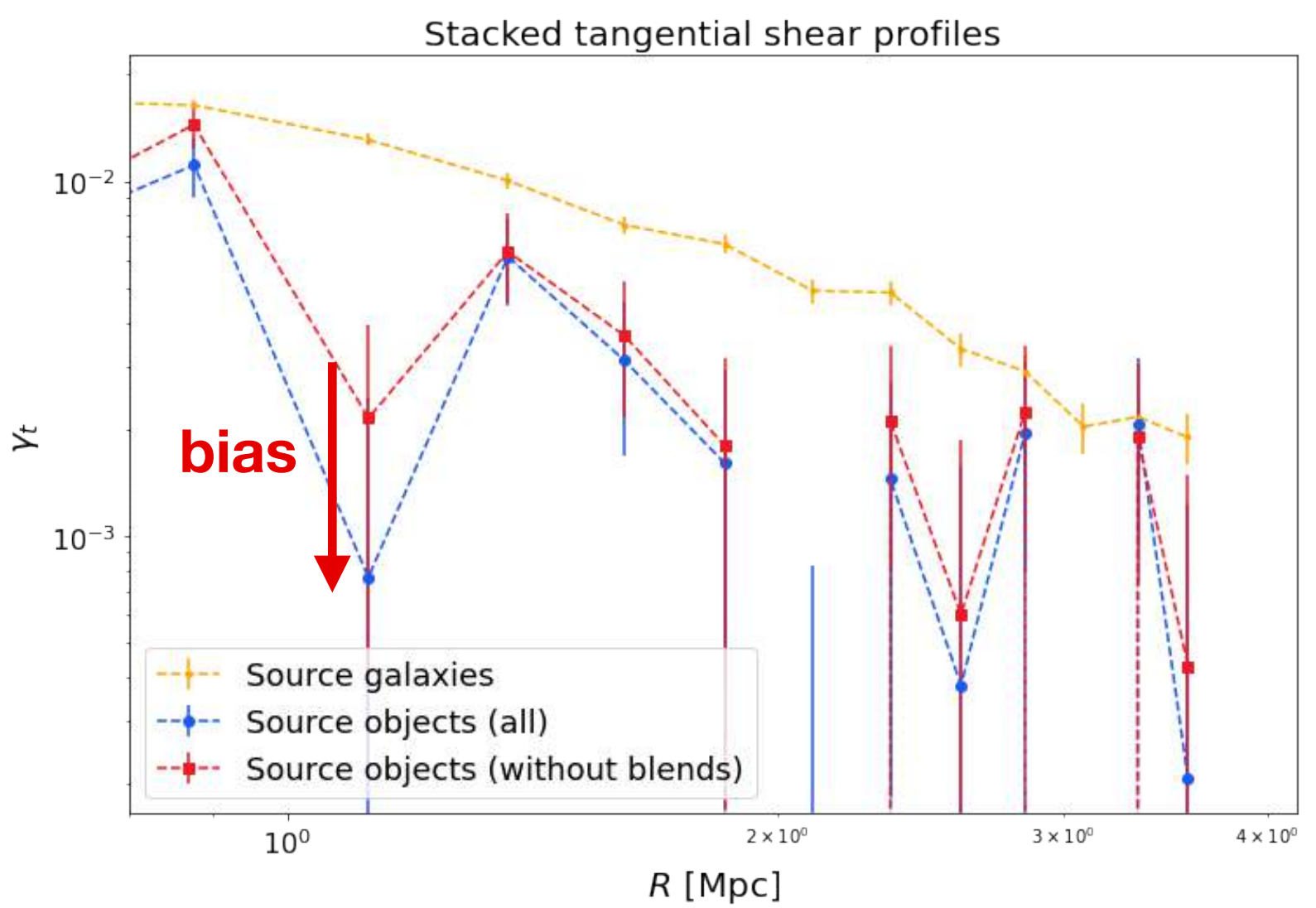
36 haloes: $M_{lens} = 1.64 \cdot 10^{14} M_\odot$
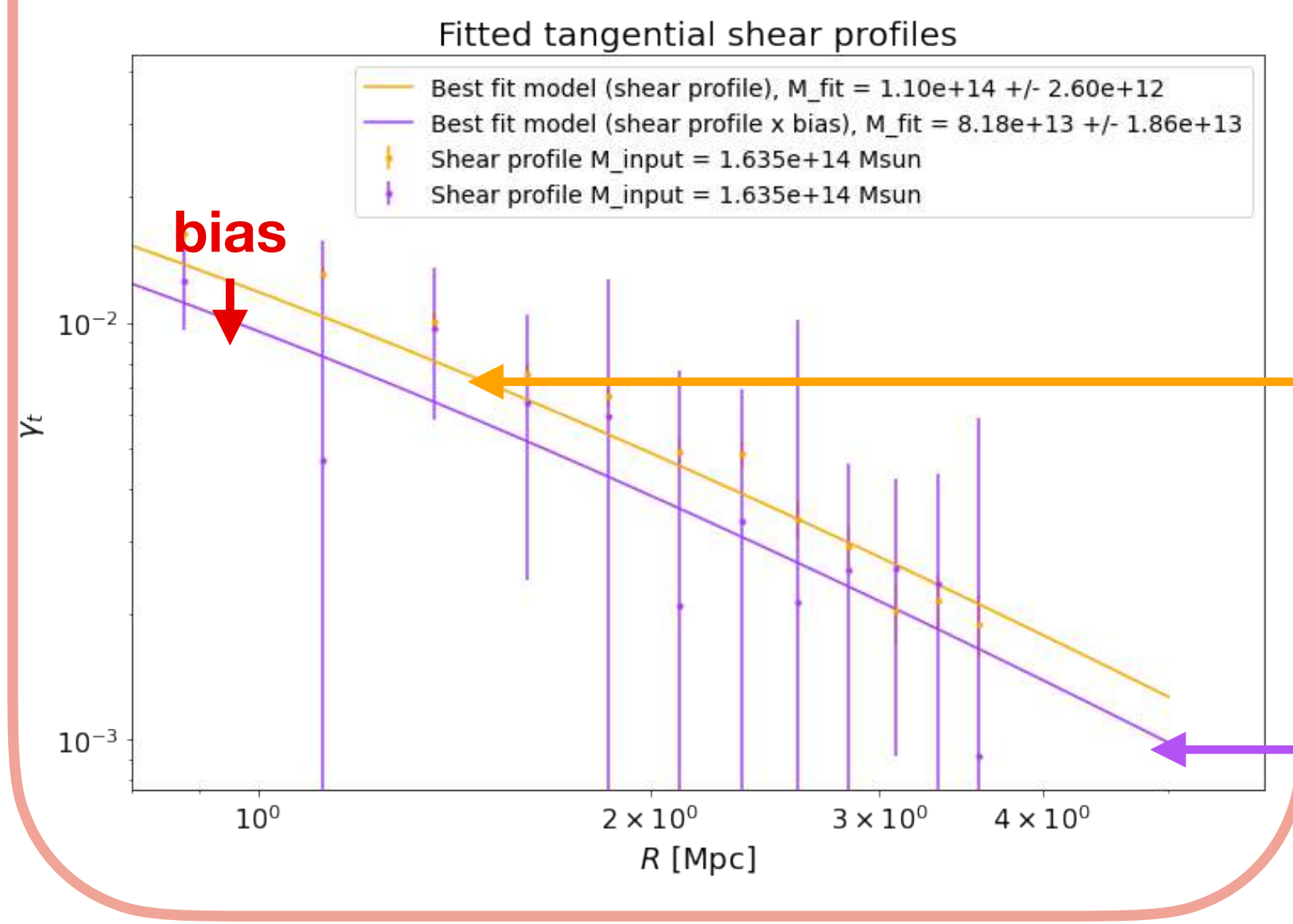
bias

bias

Shear profile:
$M_{200} = (1.10 \pm 0.02) \cdot 10^{14} \mathrm{M}_\odot$

Biased shear profile:
$M_{200} = (0.81 \pm 0.18) \cdot 10^{14} \mathrm{M}_\odot$

Systematic bias = $\dfrac{\gamma_{t_{obj}}}{\gamma_{t_{without\,blends}}}$

Mis/under-estimation of cluster mass due to blending

Significative bias ?
To be refined ➔ **more statistics**!

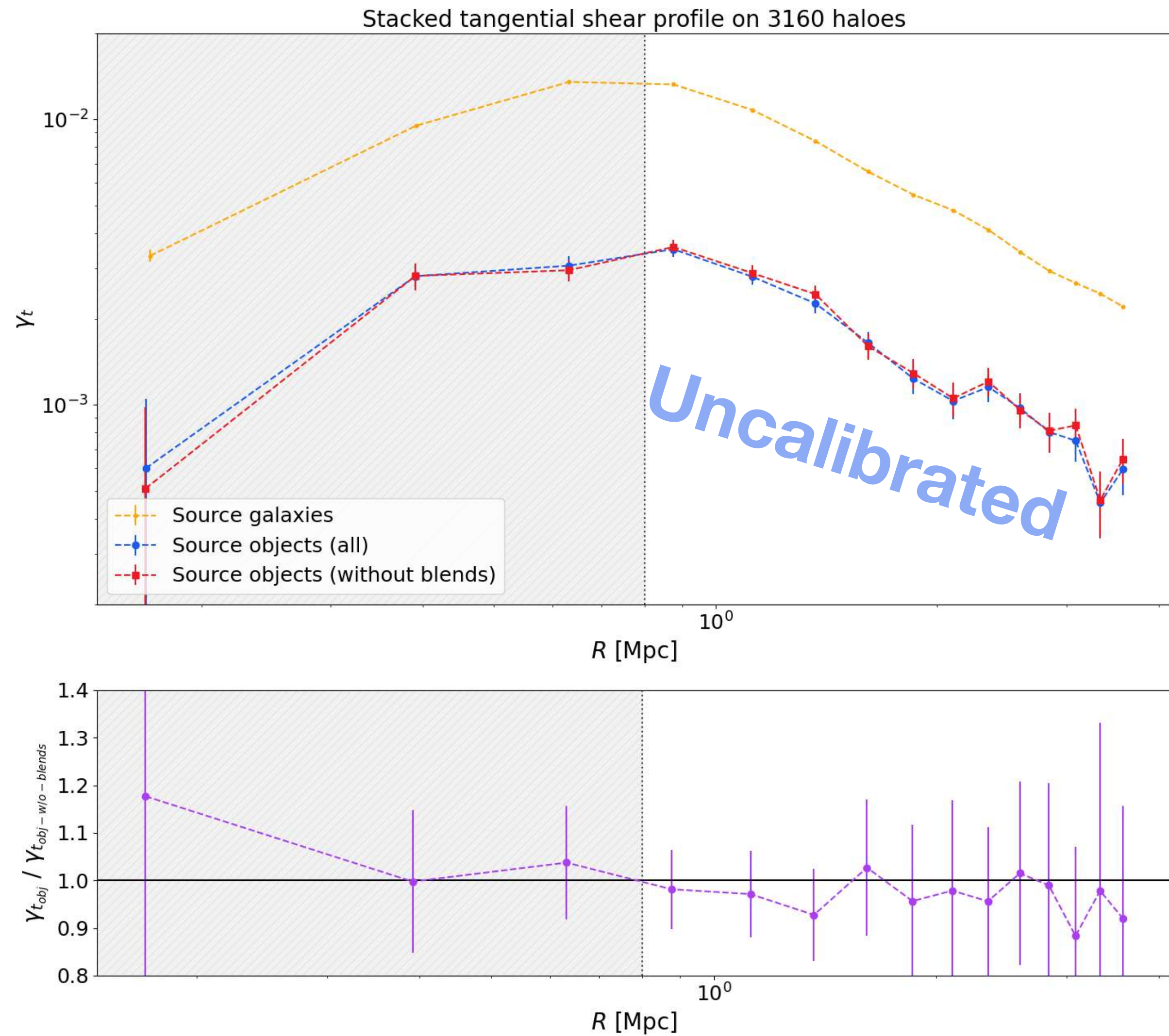# Stack on more haloes to increase statistics

Stacked tangential shear profile on 3160 haloes

Stack on 3160 haloes:

- Proportion of removed objects: **9%**

Next steps:

- Apply **weights** on individual profiles before stacking
- **Bin** the results in bins of mass and redshift
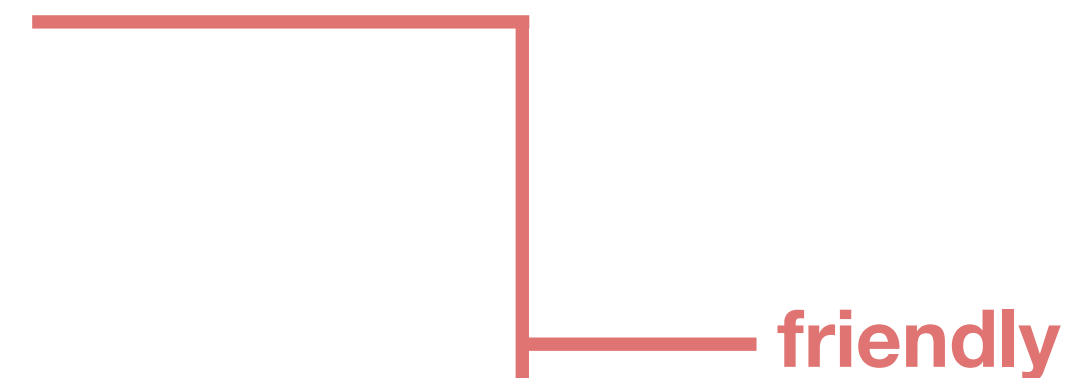
- **Redefinition of blends**

New matching algorithm: friendly

Shuang Liang, Manon Ramel, Cyrille Doux, Marine Kuna, Alex Malz, Ismael Mendoza…
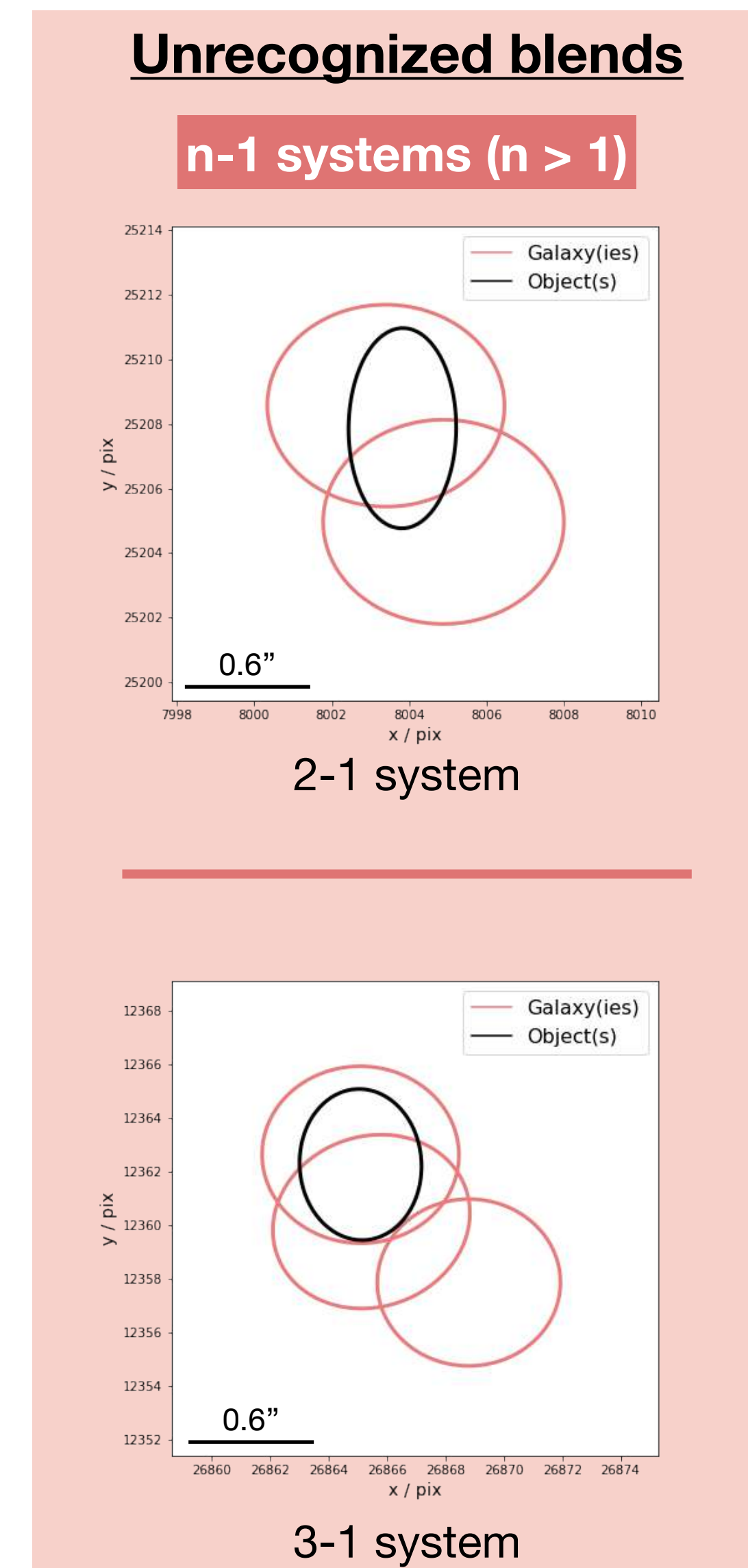*https://github.com/LSSTDESC/friendly*

1) Friends-of-Friends matching

friendly

2) Ellipticities overlap test

3) Metrics on blended systems — **lost-and-found**
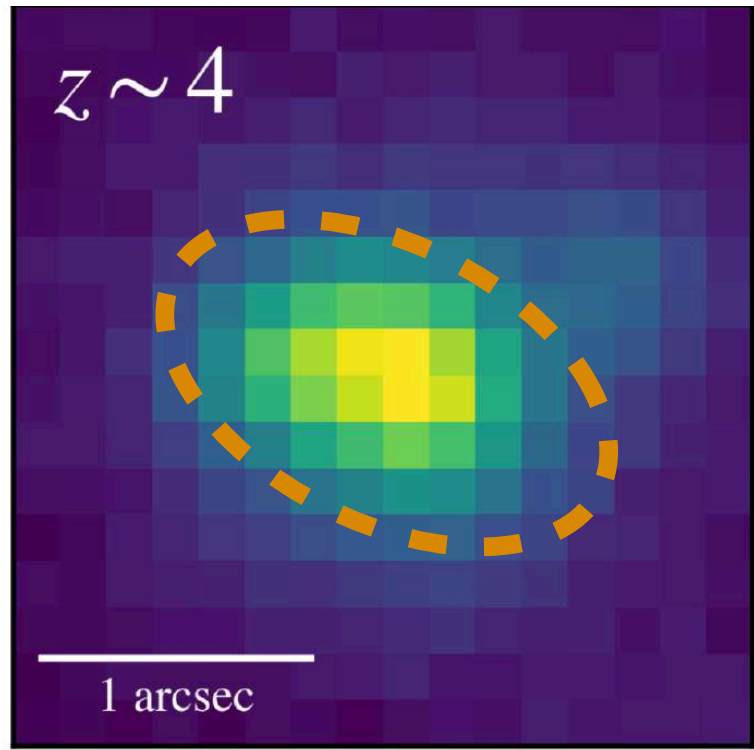
- Distribution of blended systems in galaxy clusters
- Impact of blending on shear measurements

Perfect matches

1-1 systems

Unrecognized blends

n-1 systems (n > 1)

2-1 system

Recognized blends

n-n systems (n > 1)

2-2 system

3-1 system

Conclusion

$z \sim 4$

1 arcsec
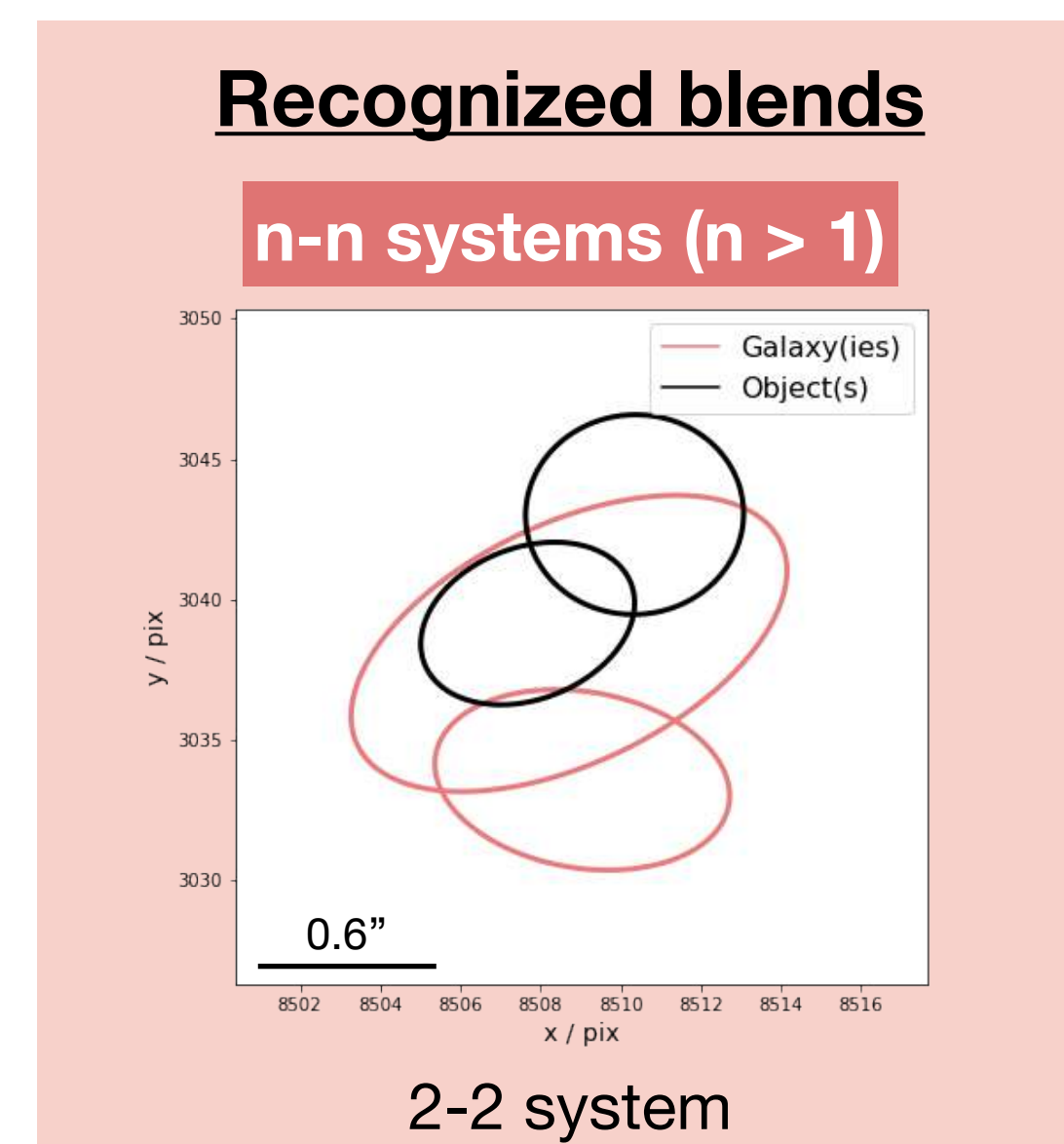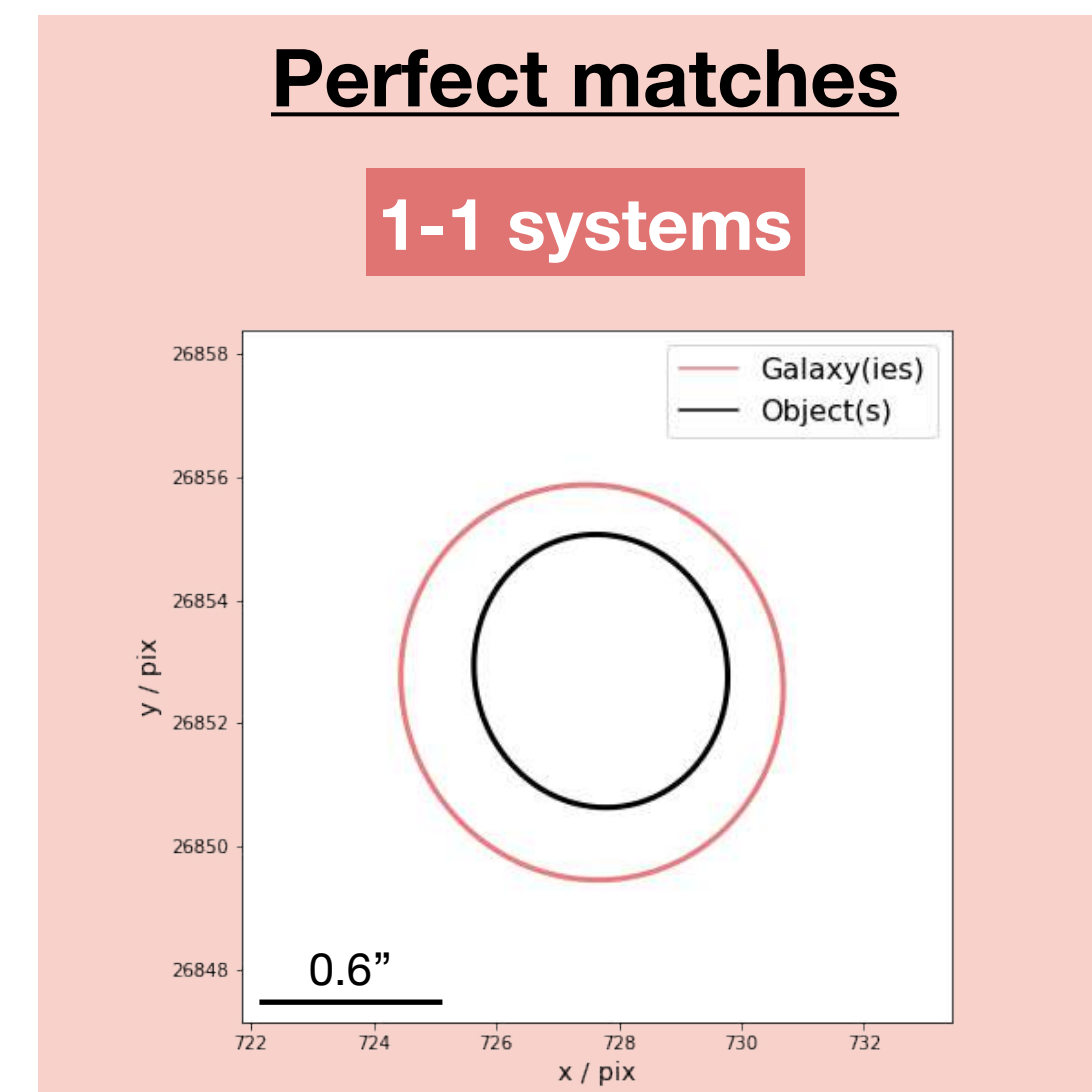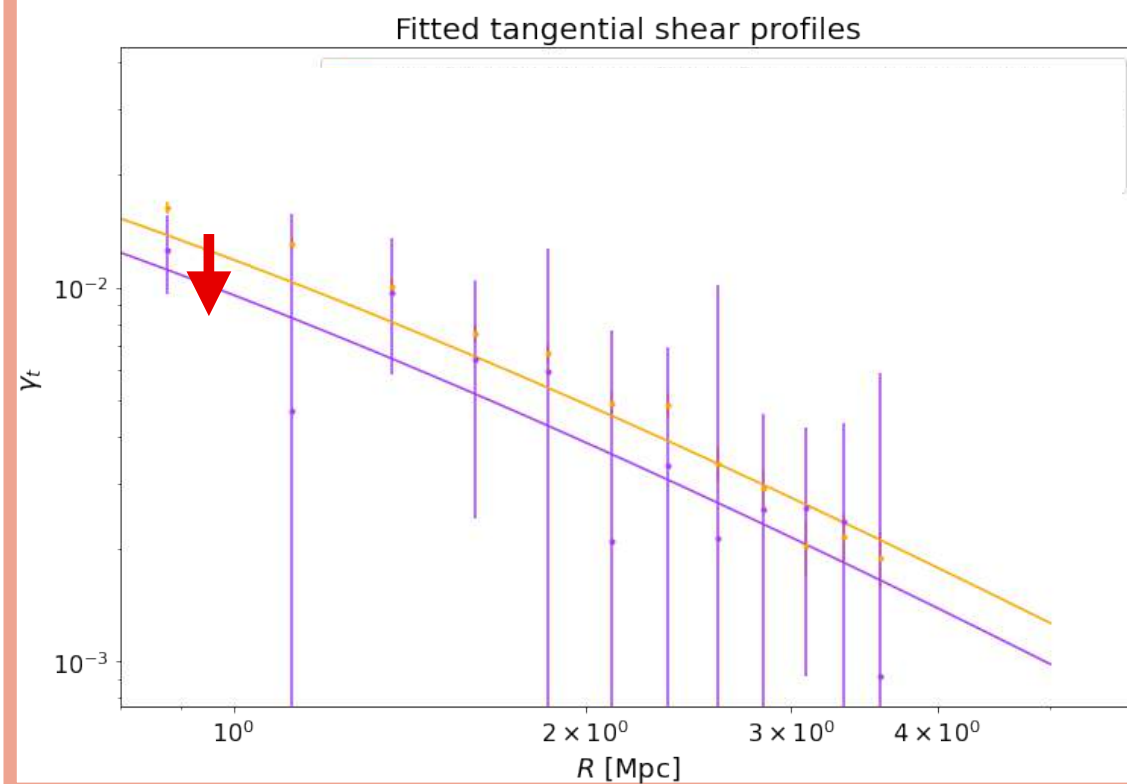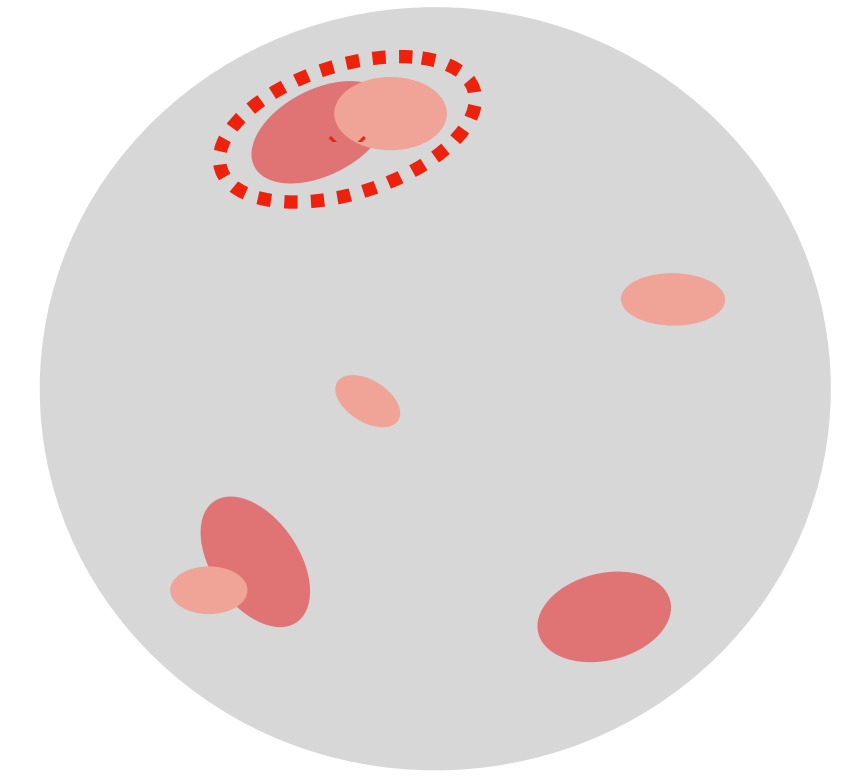
Impact of the unrecognized blends on the detection of individual galaxies

Proportion and distribution of blends inside galaxy clusters, working on dark matter haloes

Fitted tangential shear profiles

Impact of blending on galaxy cluster mass estimates and on cosmological parameters

Redefinition of blends through the new package friendly (work in progress)
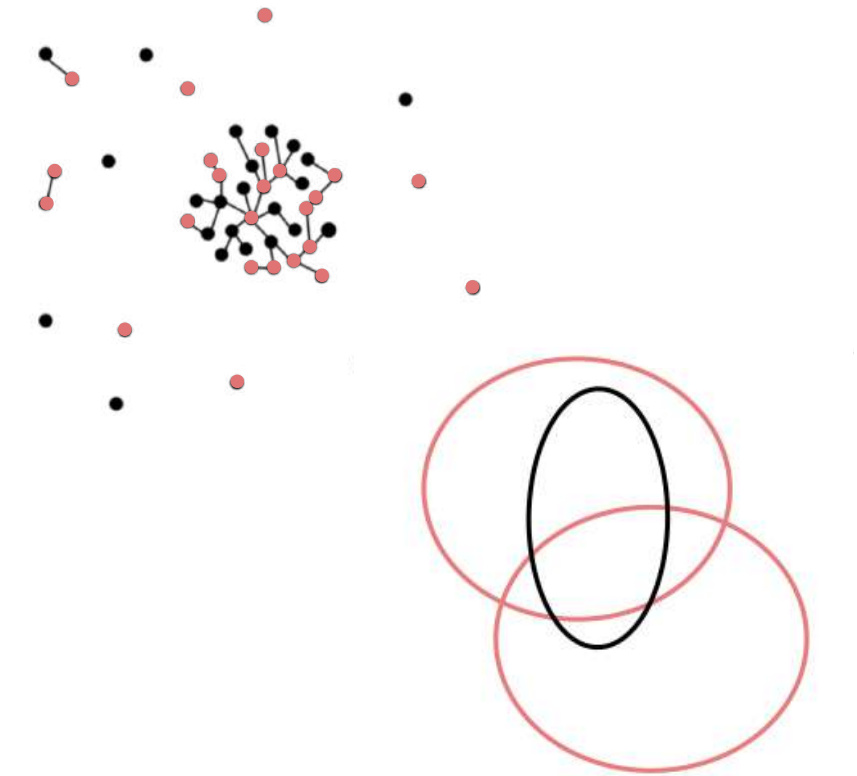
Thank you for your attention !

Laboratoire de Physique Subatomique & Cosmologie

Supervisors : Cyrille Doux, Marine Kuna

Mass function

$z = 0.5$; $\sigma_8 = 0.8$ $z = 0.5$; $\Omega_m = 0.3$

Legend (left panel):
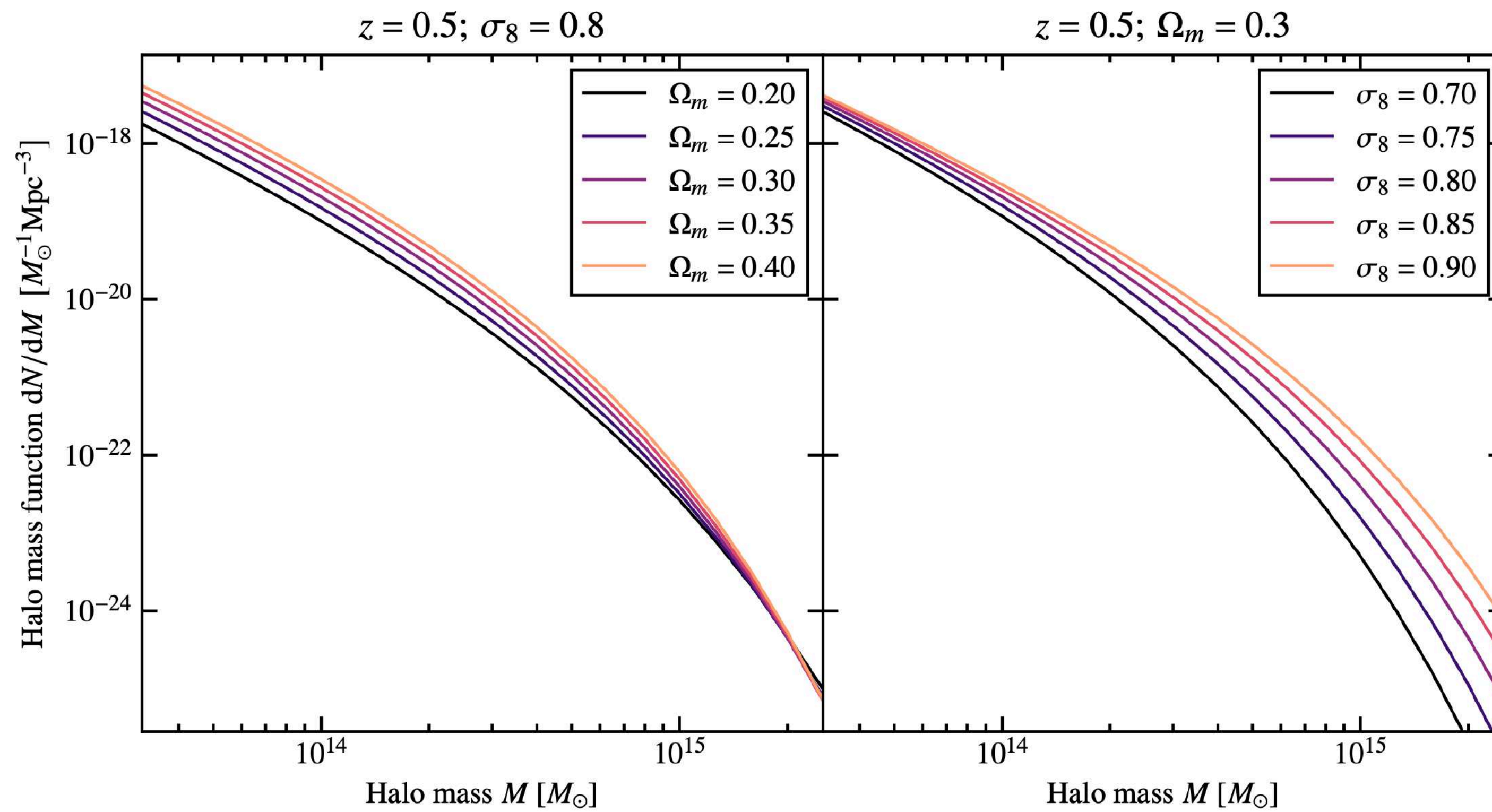- $\Omega_m = 0.20$
- $\Omega_m = 0.25$
- $\Omega_m = 0.30$
- $\Omega_m = 0.35$
- $\Omega_m = 0.40$

Legend (right panel):
- $\sigma_8 = 0.70$
- $\sigma_8 = 0.75$
- $\sigma_8 = 0.80$
- $\sigma_8 = 0.85$
- $\sigma_8 = 0.90$

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

X axis: Halo mass M $[M_\odot]$

Cluster count :

$$N = \int_{z_{min}}^{z_{max}} dz \frac{dV}{dz} \int_{m_{min}}^{m_{max}} dm \frac{dn(m,z)}{dm}$$
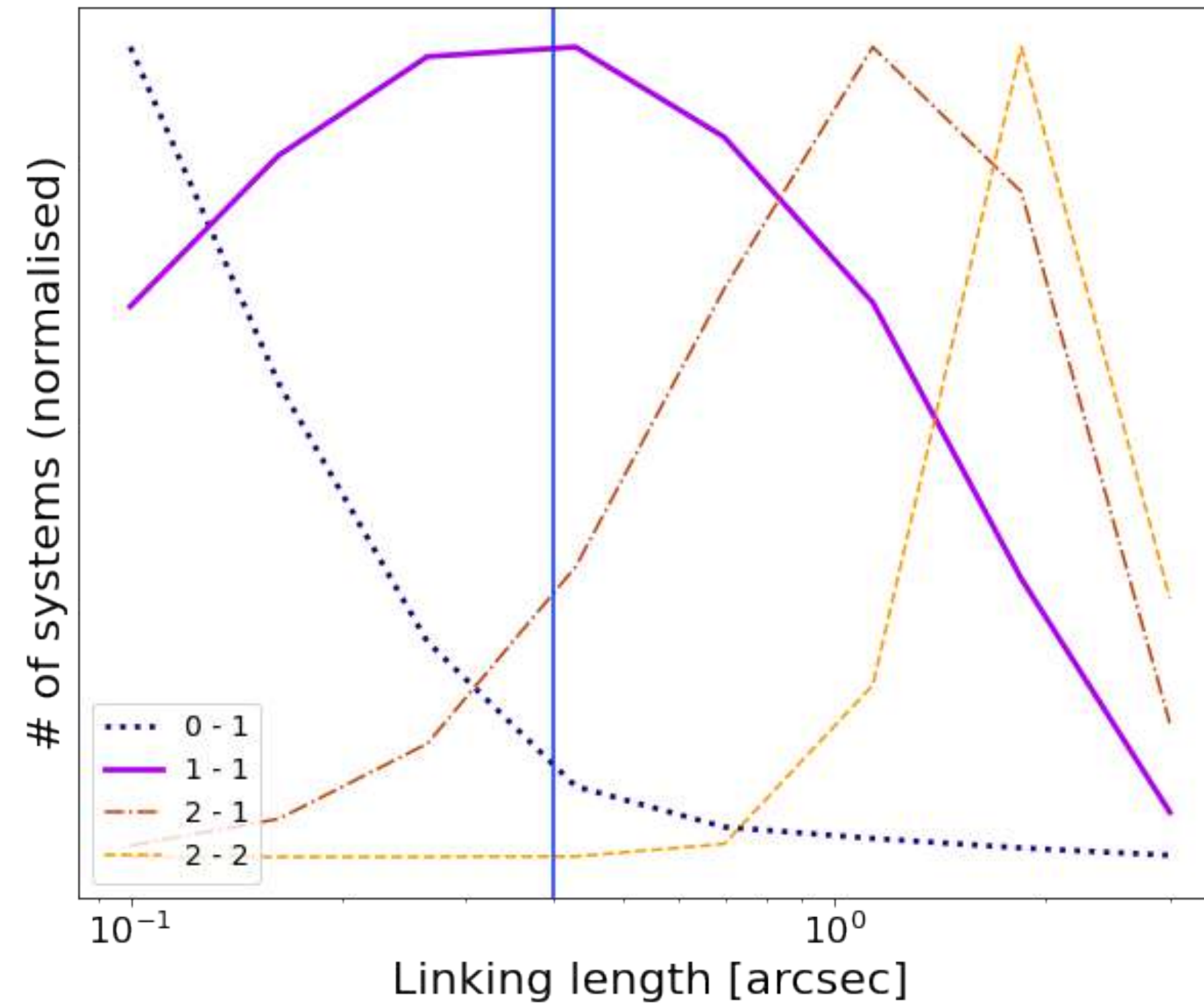
Redshift   Mass

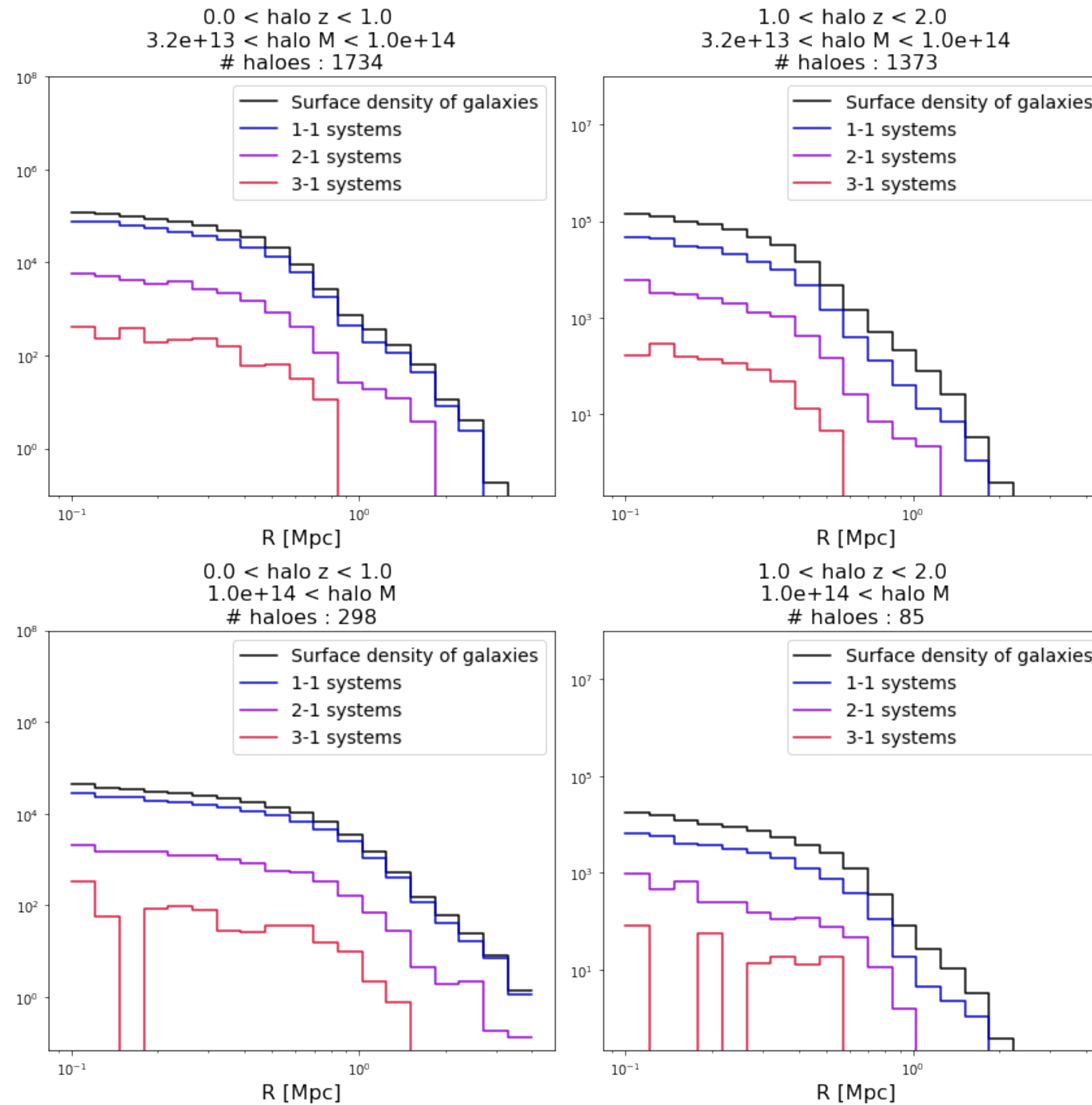# Choice of the linking length

Maximize the 1-1 systems = perfect matches

We choose: 0.4"   (pixel size: 0.2")

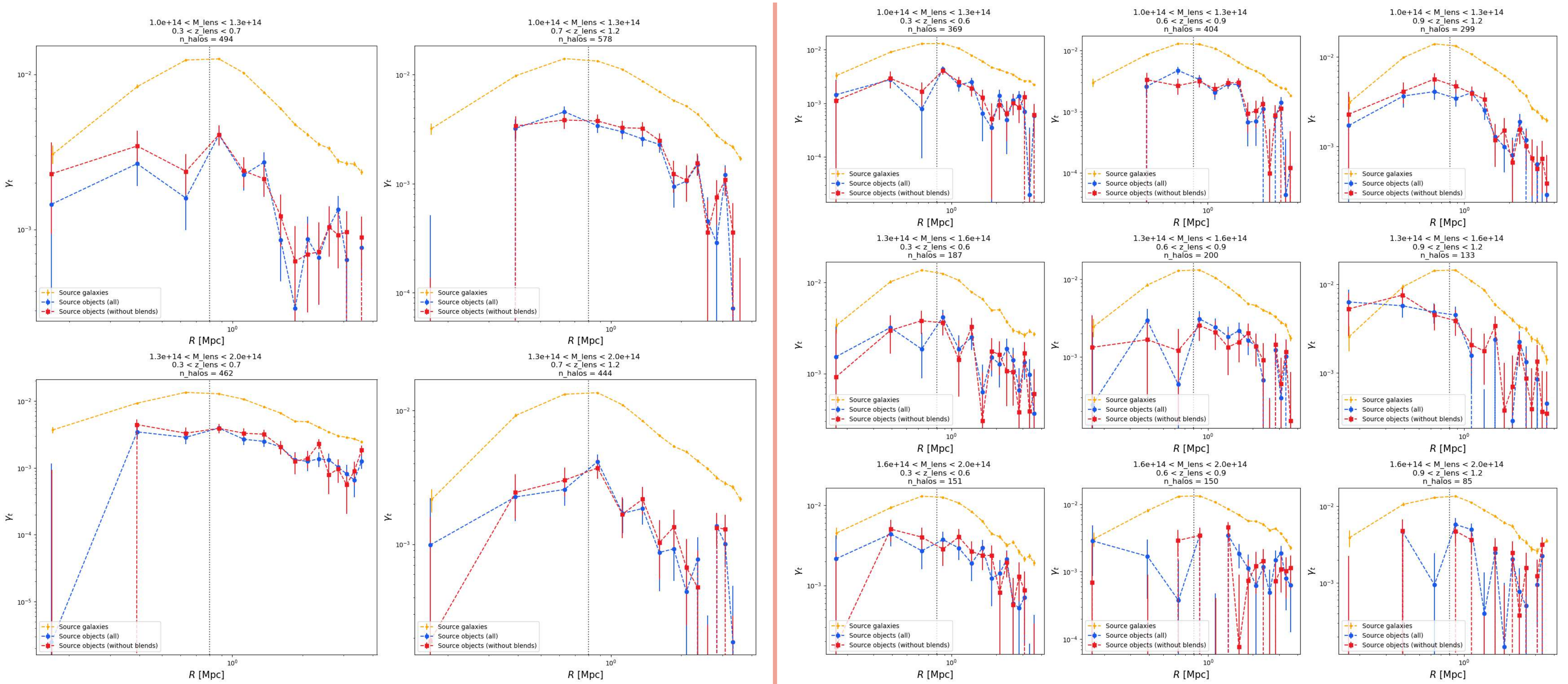- Proportion of unrecognized blends (n-1 systems with n > 1) : ~ 8%

Blended systems demography

Impact of blending on shear profiles (binned profiles)

Impact of blending on shear profiles (linking length = 1")

Stacked tangential shear profile on 3160 profiles

Legend:
- Source galaxies
- Source objects (all)
- Source objects (without blends)

Axes: γ_t vs R [Mpc]