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Weak Lensing Simulations for Future Surveys: Euclid

Challenging small scales using future survey data and weak lensing

Carlo Giocoli: cgiocoli.wordpress.com

COLLABORATORS

Variety of observables interesting for different groups

- Lensing Simulations: M. Meneghetti, R. B. Metcalf, L. Moscardini…
- Galaxy Clusters: L. Moscardini, M. Meneghetti, S. Ettori, M. Bolzonella, O. Cucciati, F. Marulli, M. Sereno…
- Redshift Evolution of the Galaxy Population: L. Pozzetti, M. Bolzonella, F. Farsian, L. Bisigello, Xavier Lopez…
- Cosmological Simulations and non-Standard Models: M. Baldi, S. Contarini, F. Finelli, …
- AGN evolution: V. Allevato…

OUTLOOK

Simulating Observables *sometime beyond what could be analytically modelled*

- Scientific background
- New fast and efficient tool for light-cone simulations
- Simulating models beyond Vanilla ΛCDM
- Challenges within the Euclid collaboration
- Summary: what are we expecting from FUTURE SURVEYS?

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Fourier modes

k [h/Mpc]

l [1/radiants]

1 radiants is 206265 arcsec

Large k and large l mean small scales: comoving or angular

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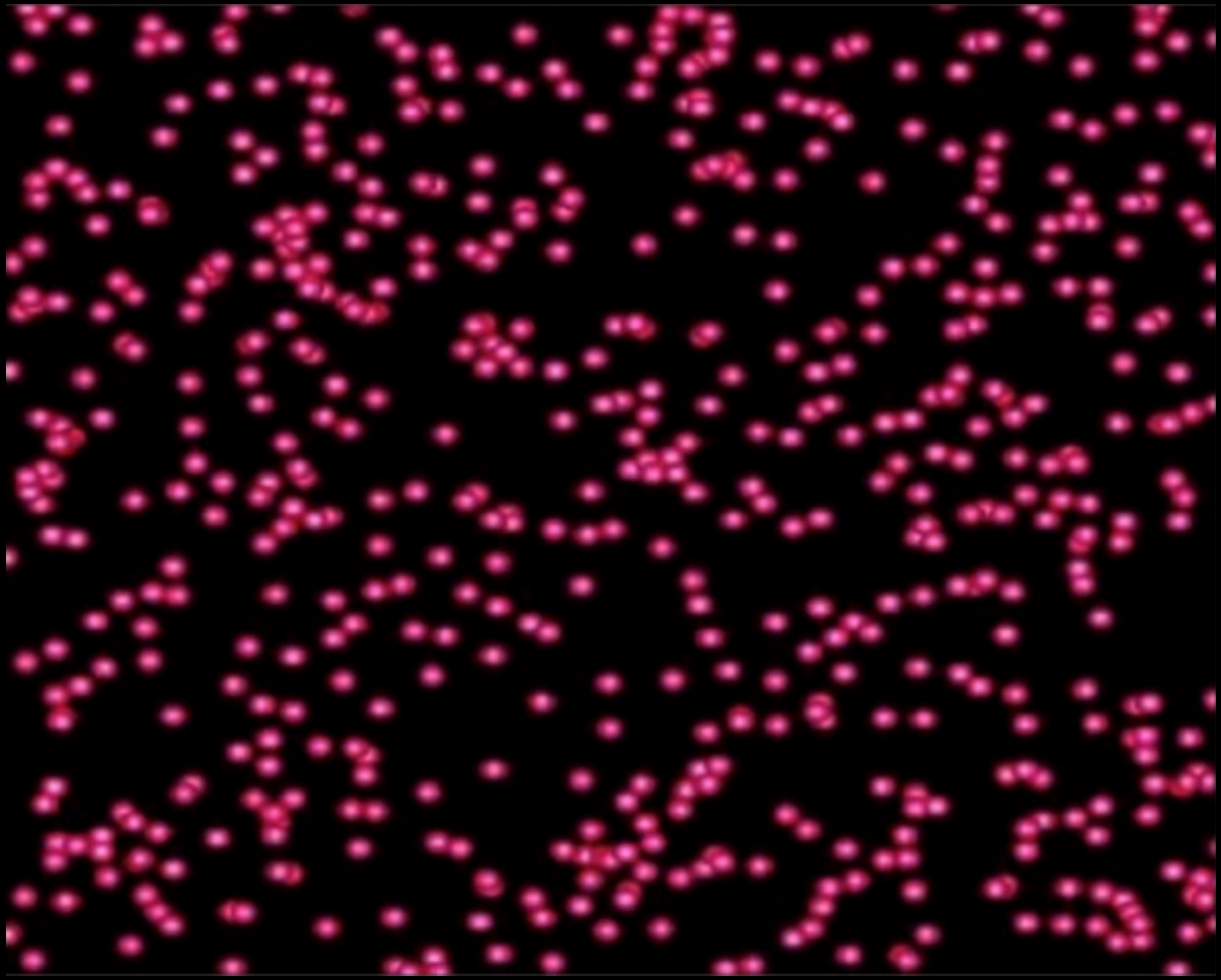
Weak Gravitational Lensing

Measuring the small intrinsic deformation of background galaxies



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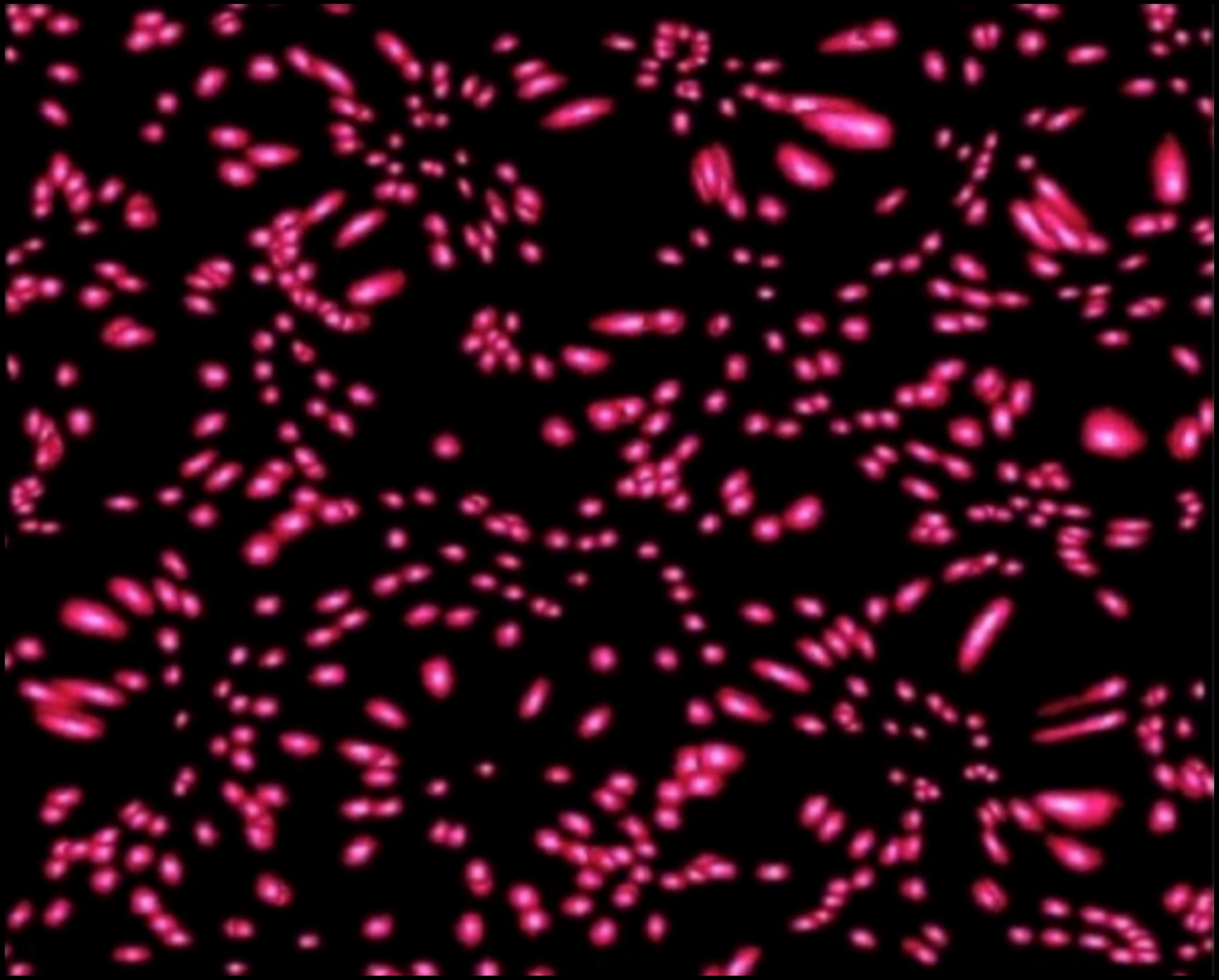

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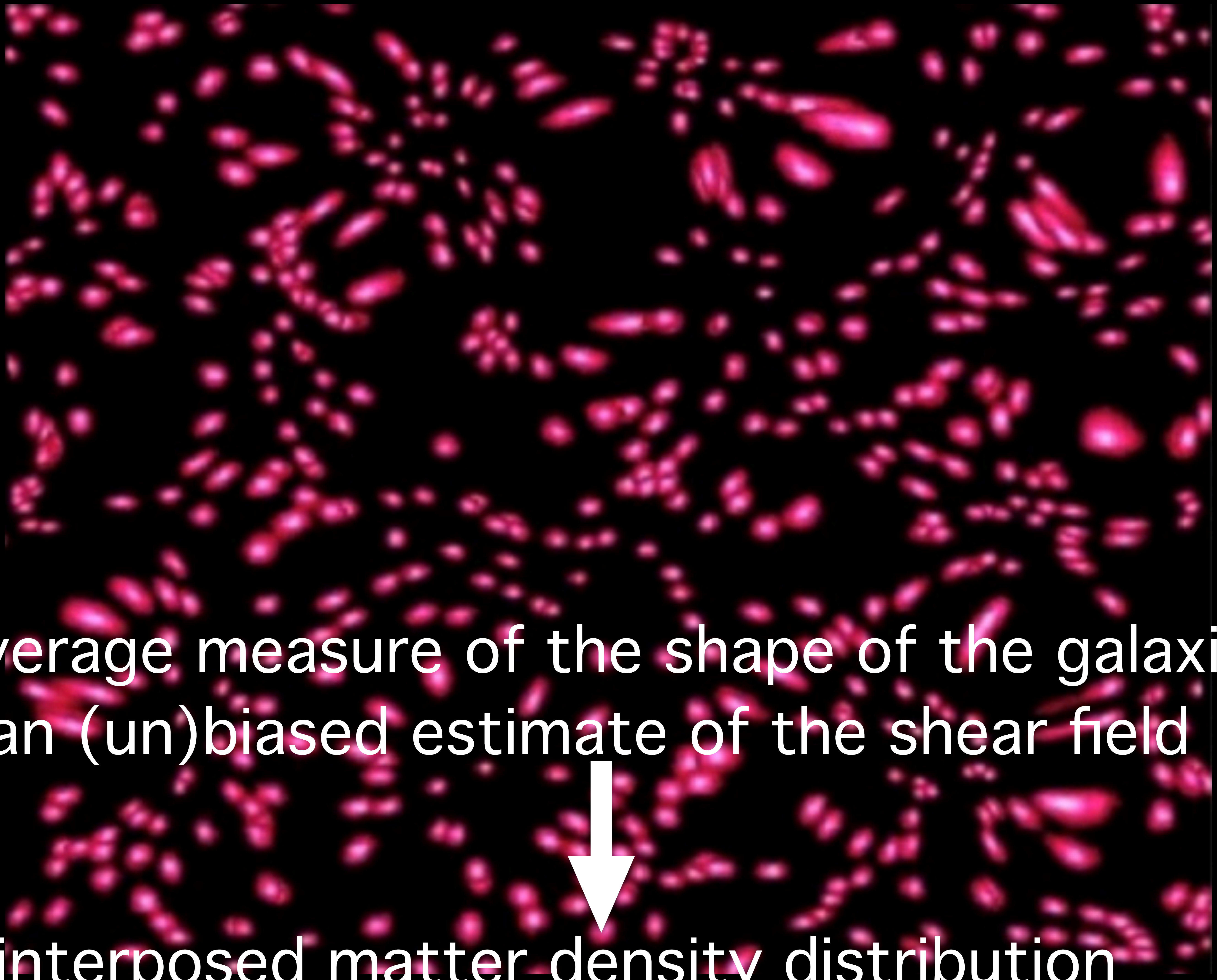
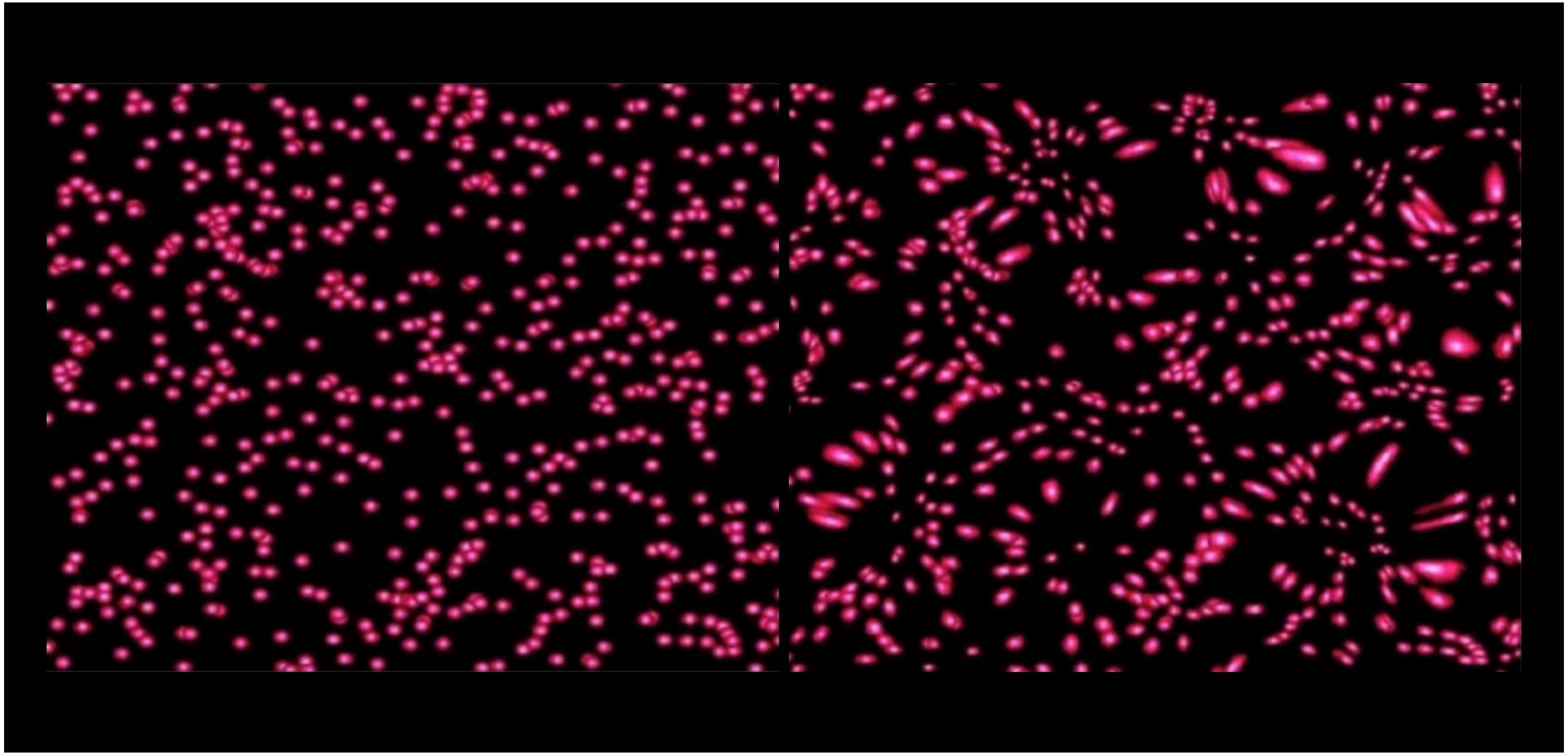
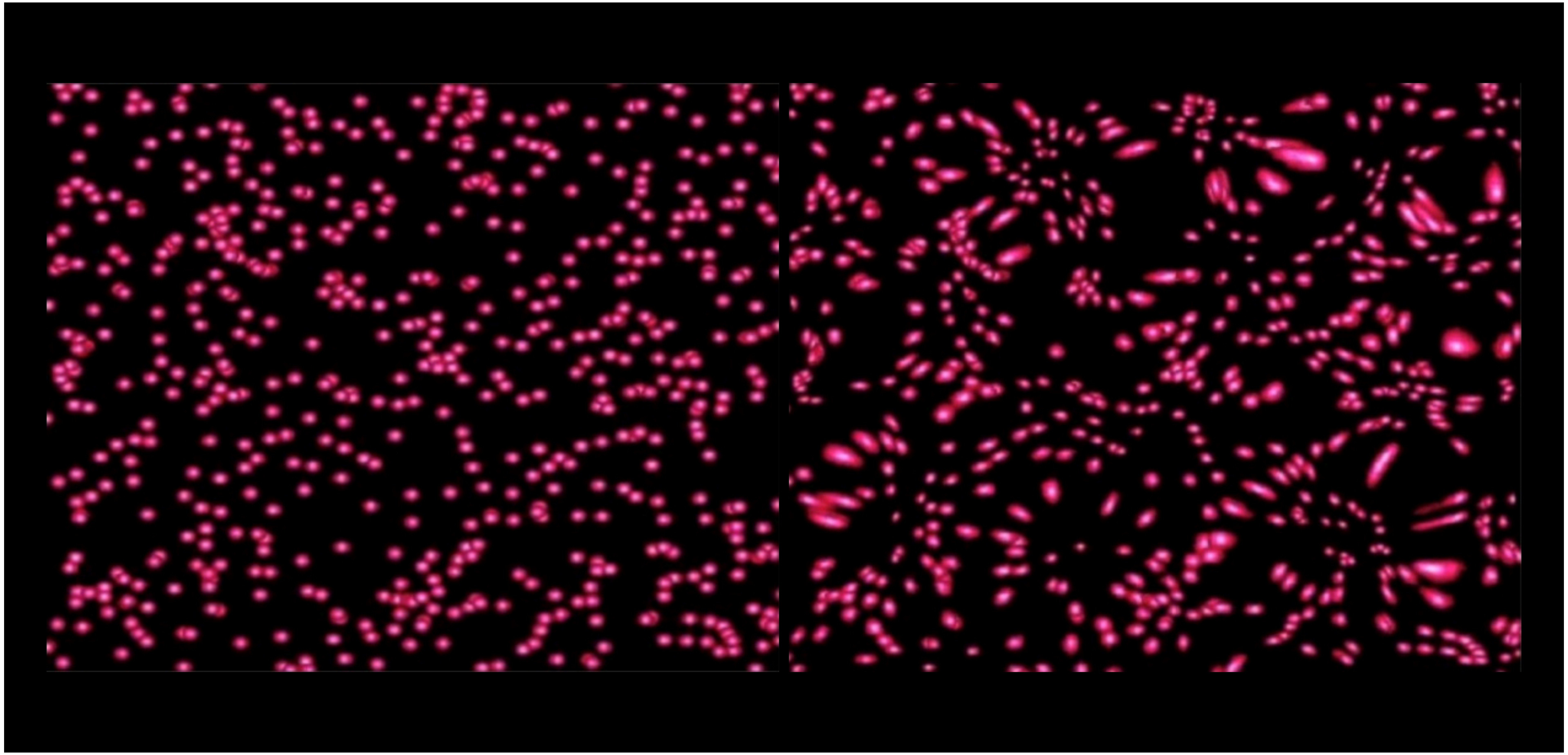


the average measure of the shape of the galaxies
is an (un)biased estimate of the shear field

interposed matter density distribution



very small effect!



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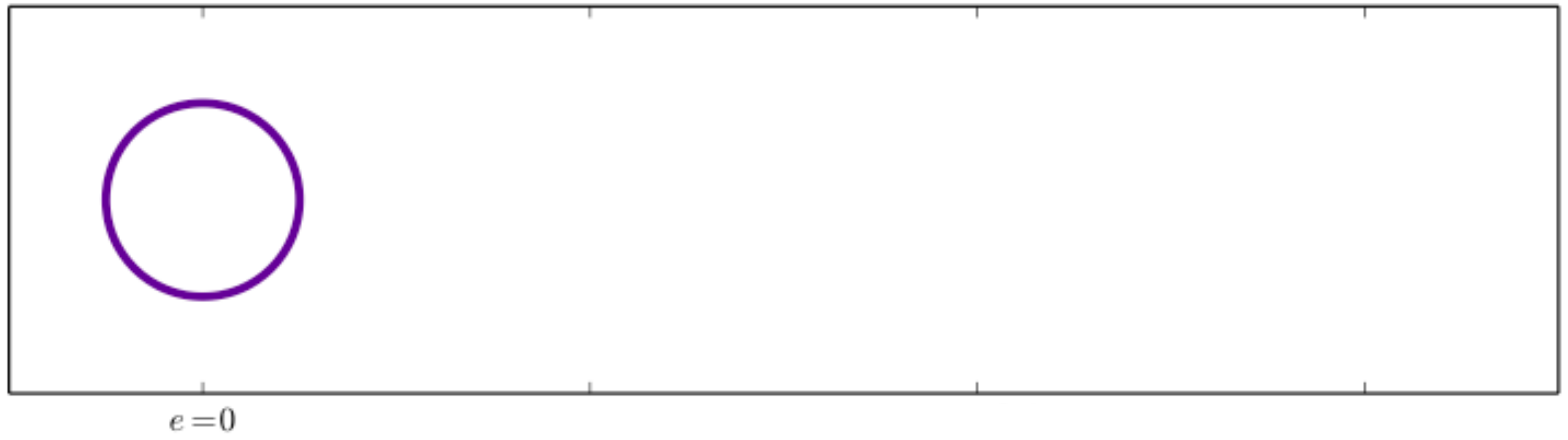
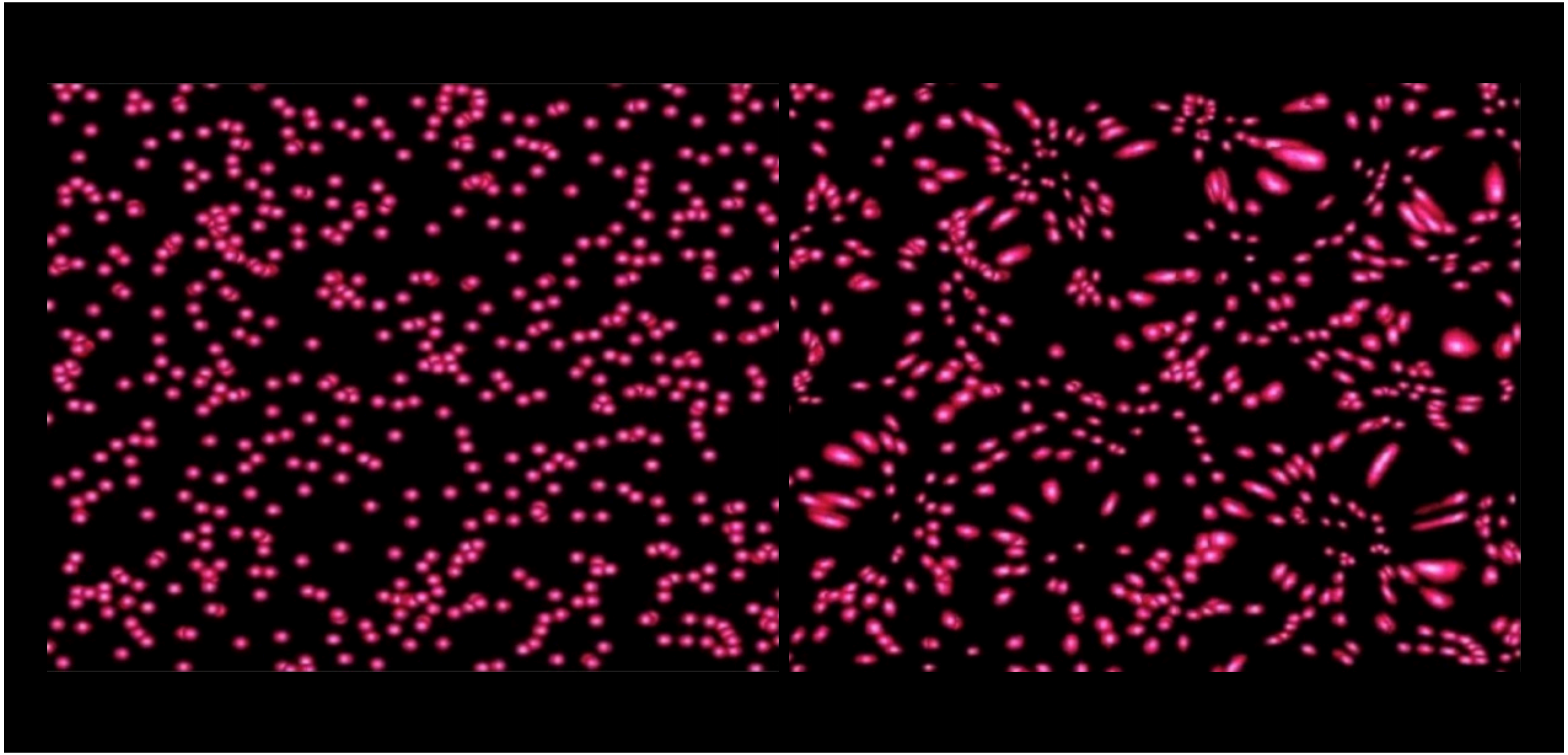


No ellipticity
$e = 0$



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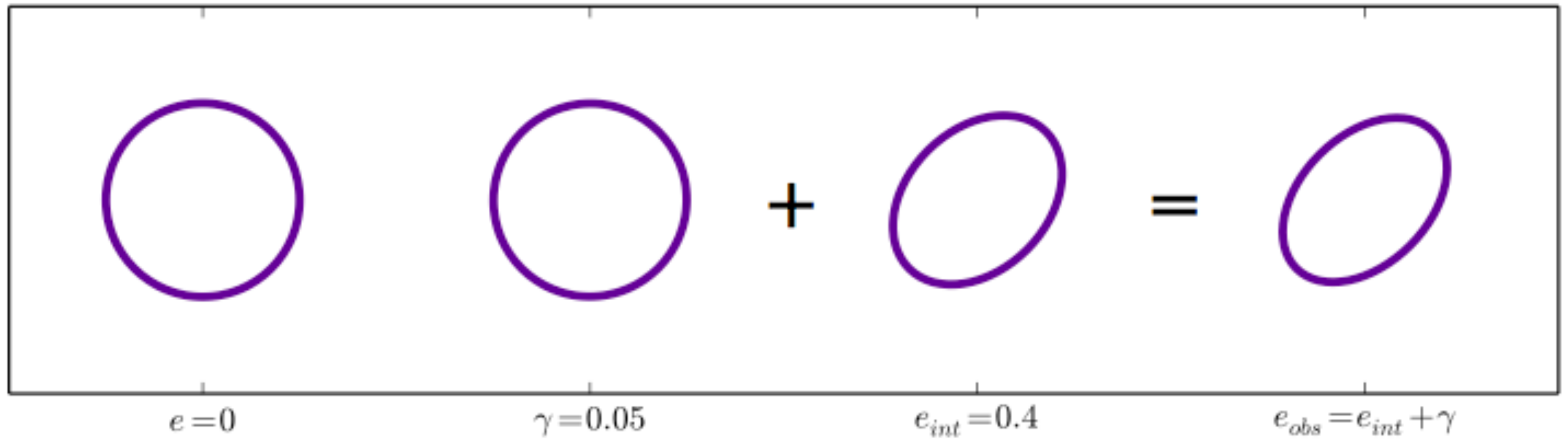


No ellipticity
$e = 0$

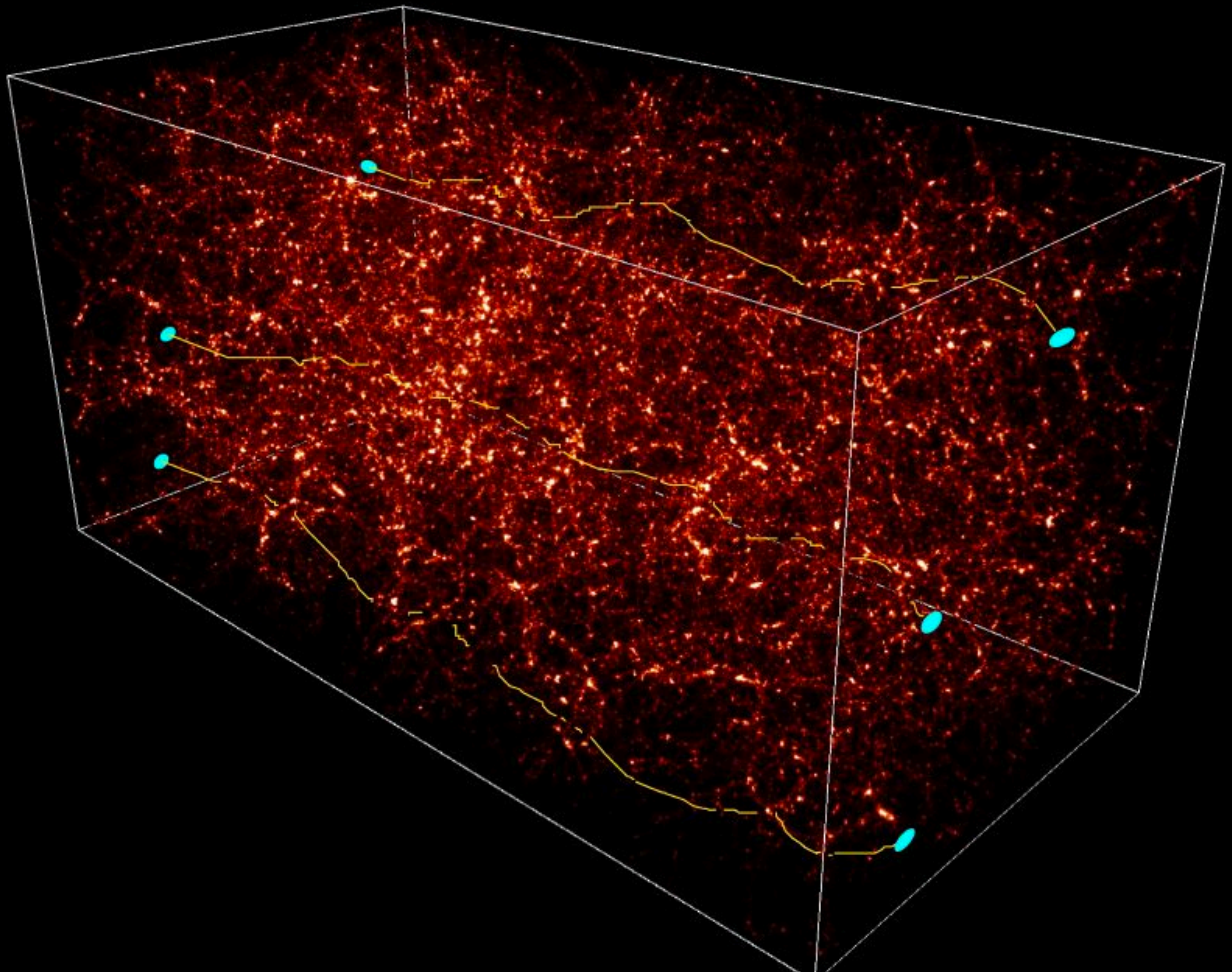
Cosmic shear
$\gamma \sim 0.05$

Galaxy ellipticity
$e \sim 0.4$

Observed ellipticity
Galaxy
+

Weak Gravitational Lensing

Measuring the small intrinsic deformation of background galaxies



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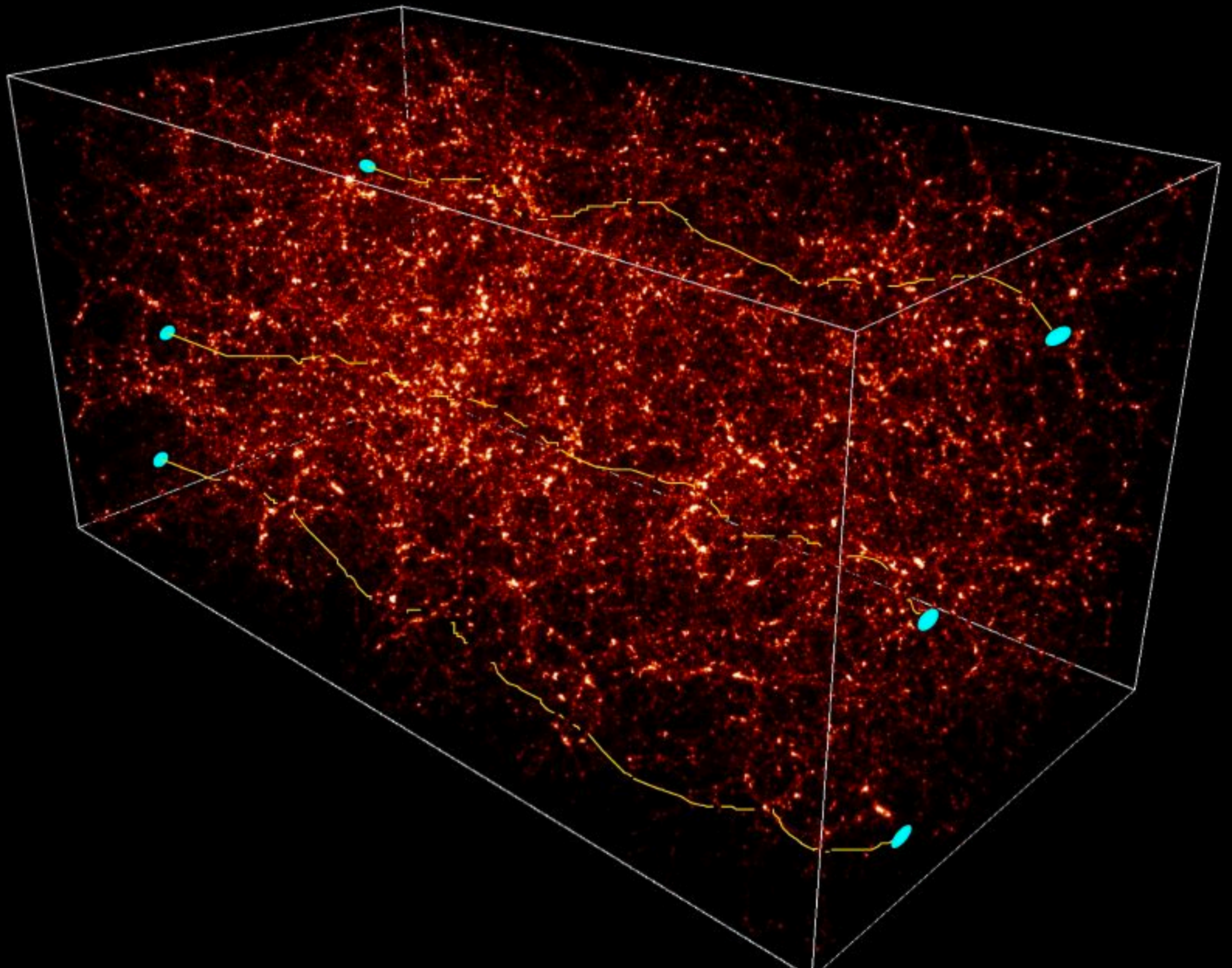
Weak Gravitational Lensing

Measuring the small intrinsic deformation of background galaxies

- primary cosmological probe



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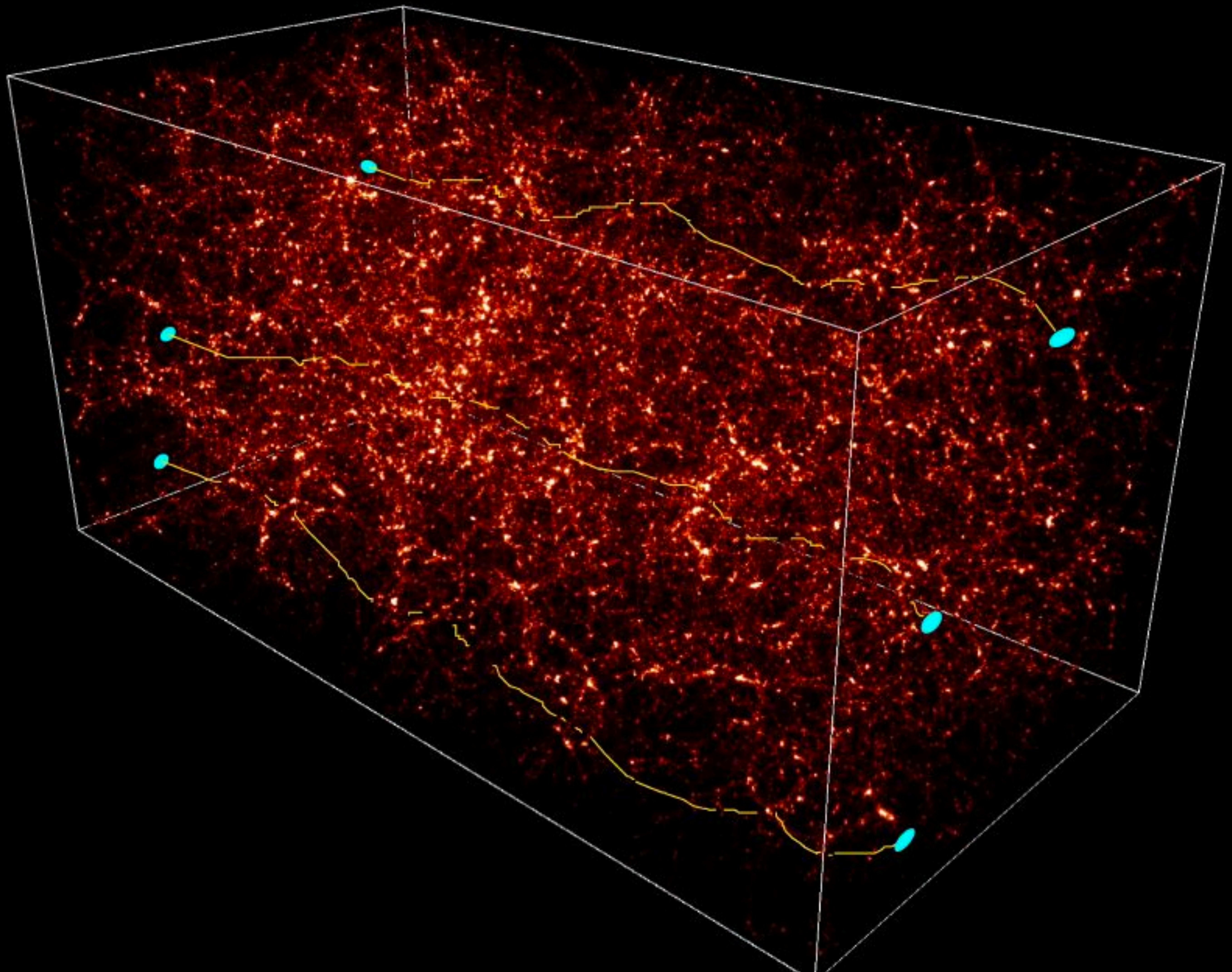
Weak Gravitational Lensing

Measuring the small intrinsic deformation of background galaxies

- primary cosmological probe
- depends on the projected matter density distribution: does not relay on any assumption on its dynamical state



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Weak Gravitational Lensing
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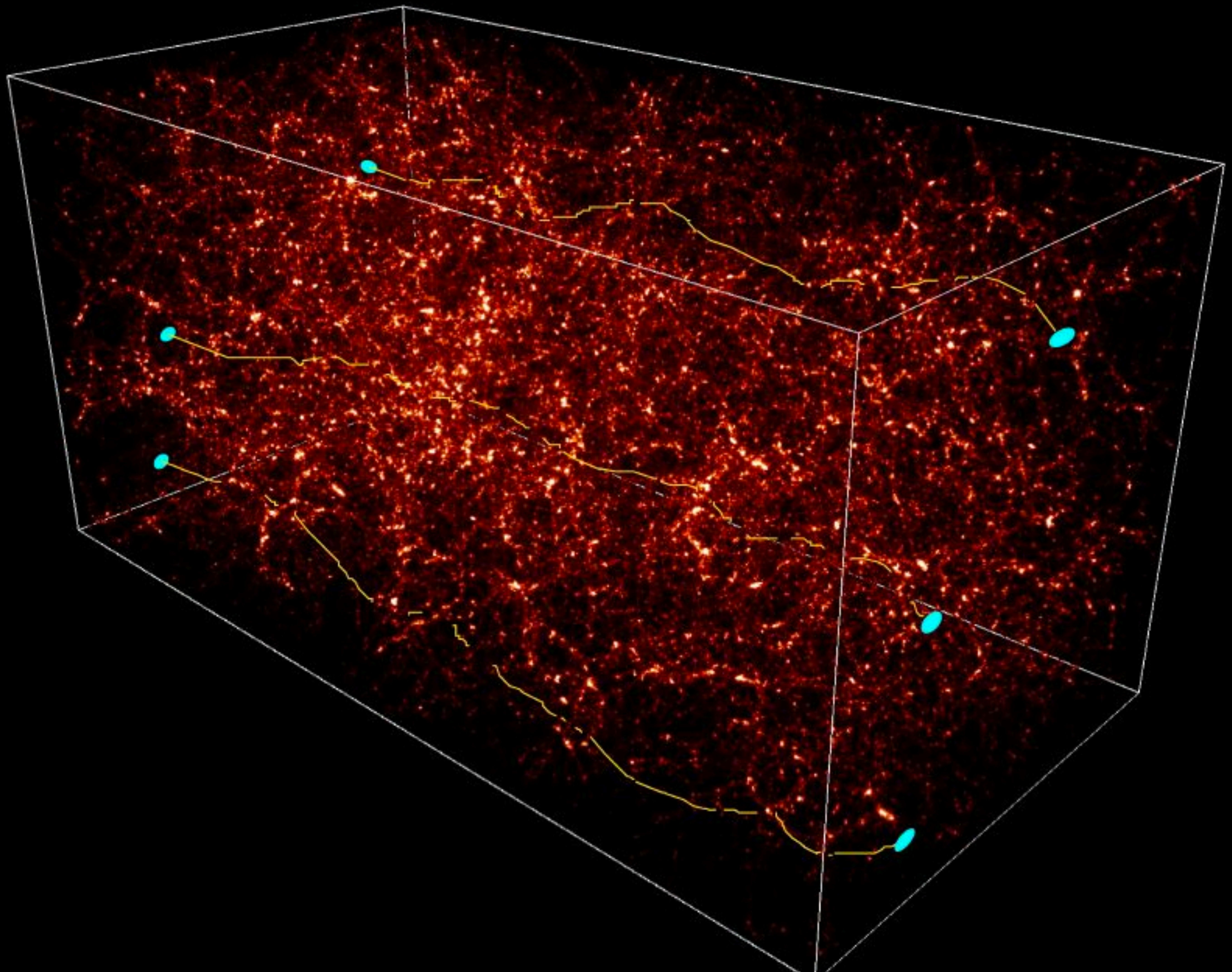

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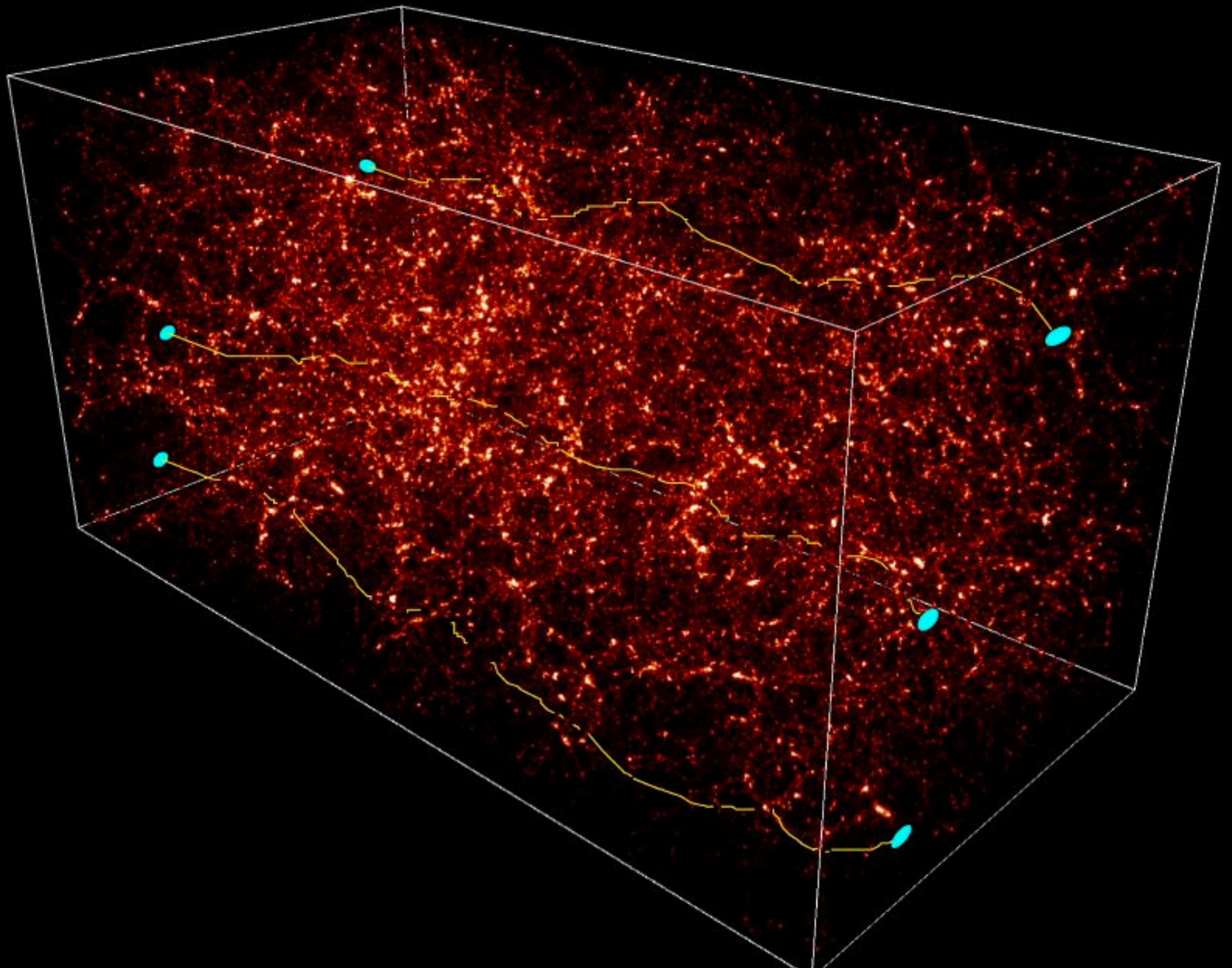

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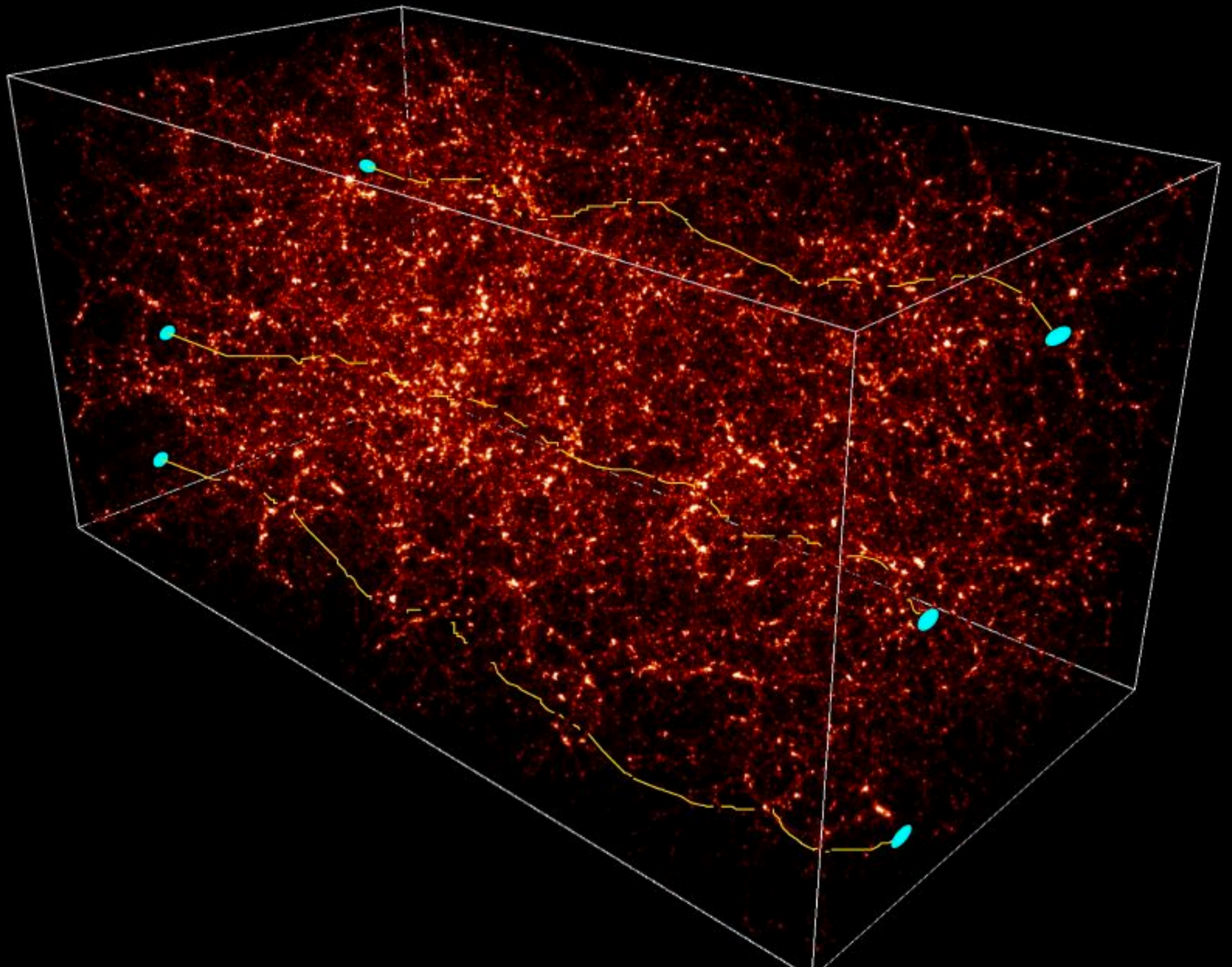
- on small scales it depends on non-linear clustering of matter: dark matter haloes & baryons
- the modification of the shape of background galaxies is very small



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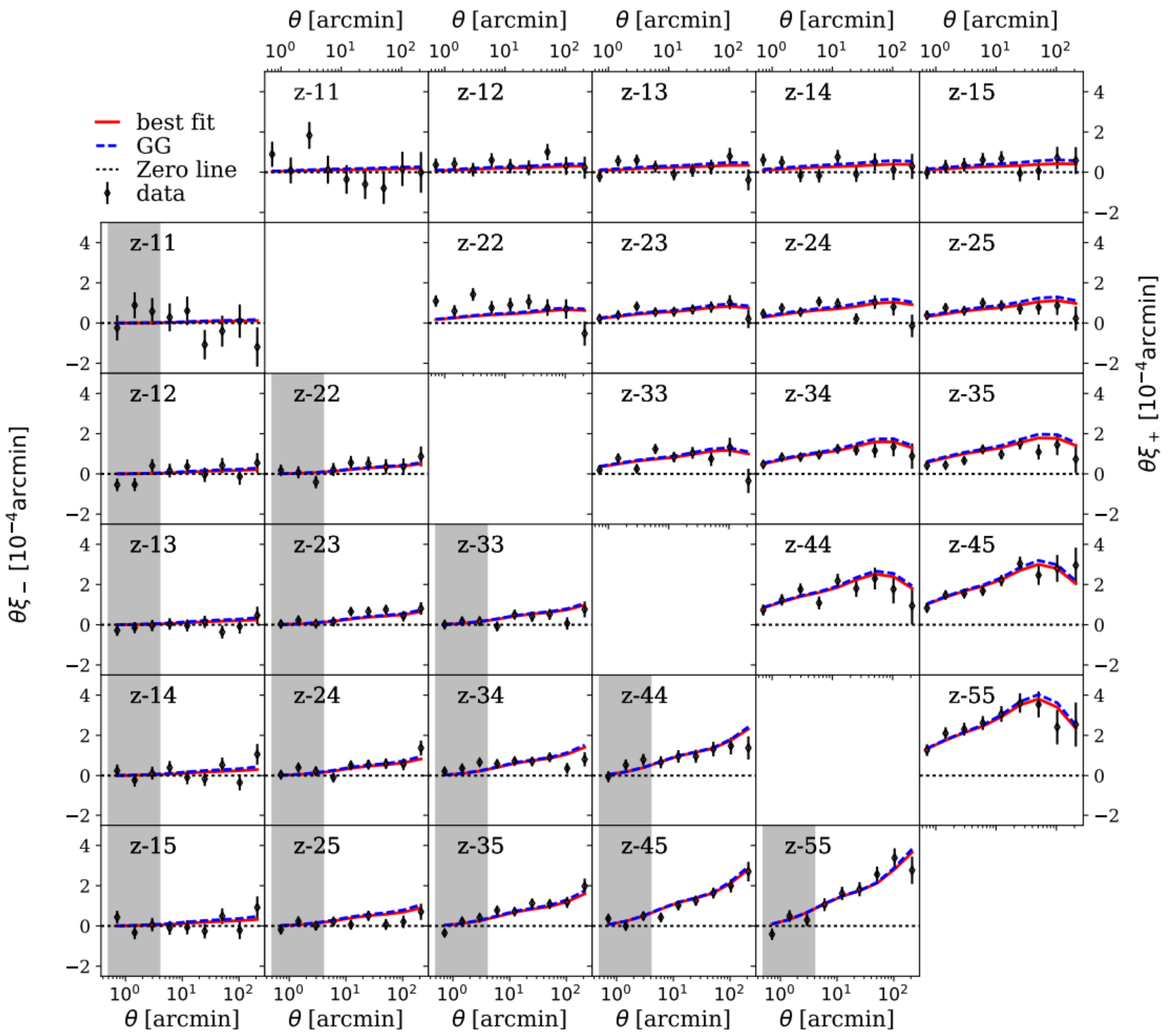
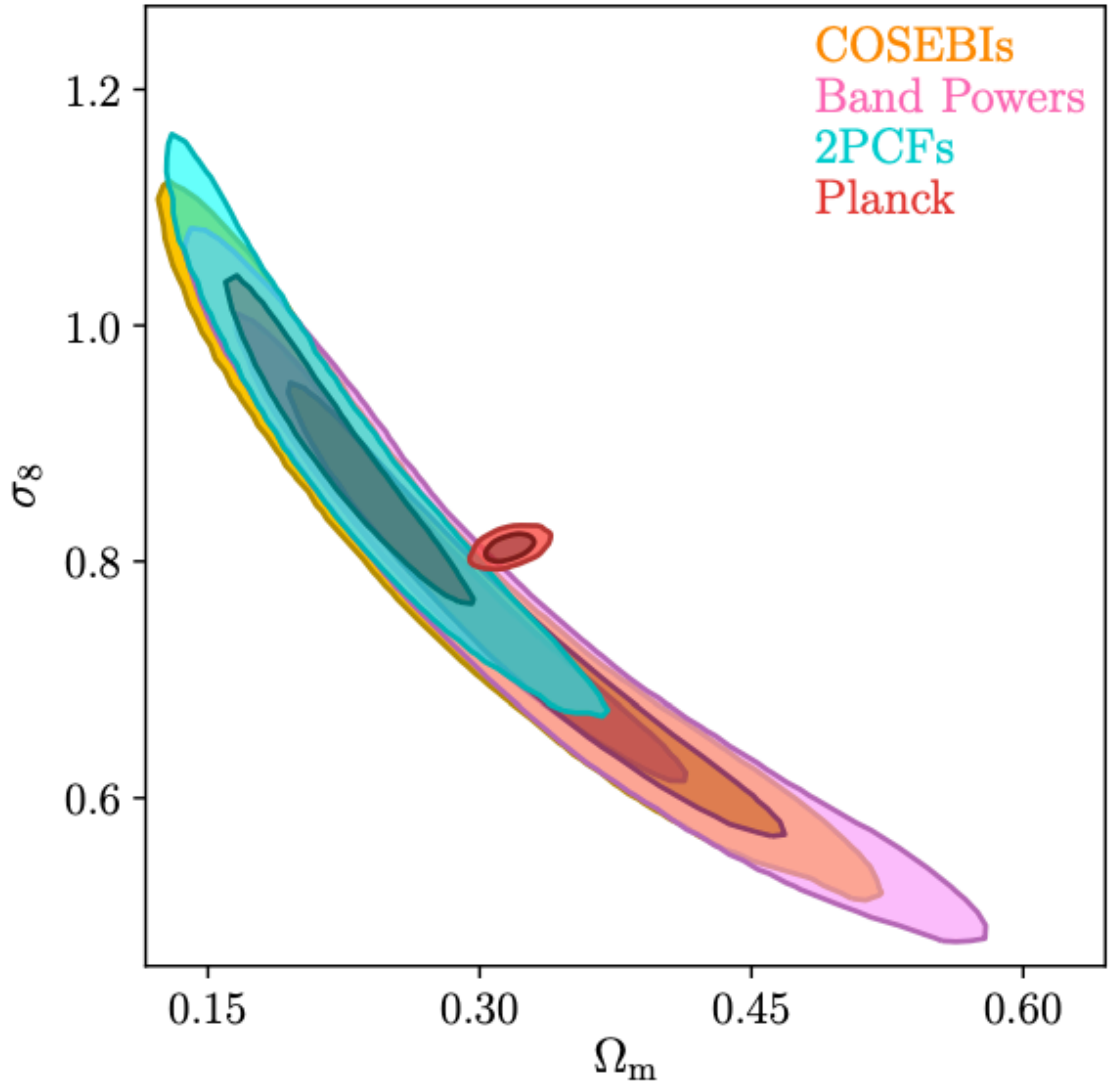
Weak Lensing

Studying the geometry and the energy budget of the Universe

KiDS-1000 Asgari et al. 2021





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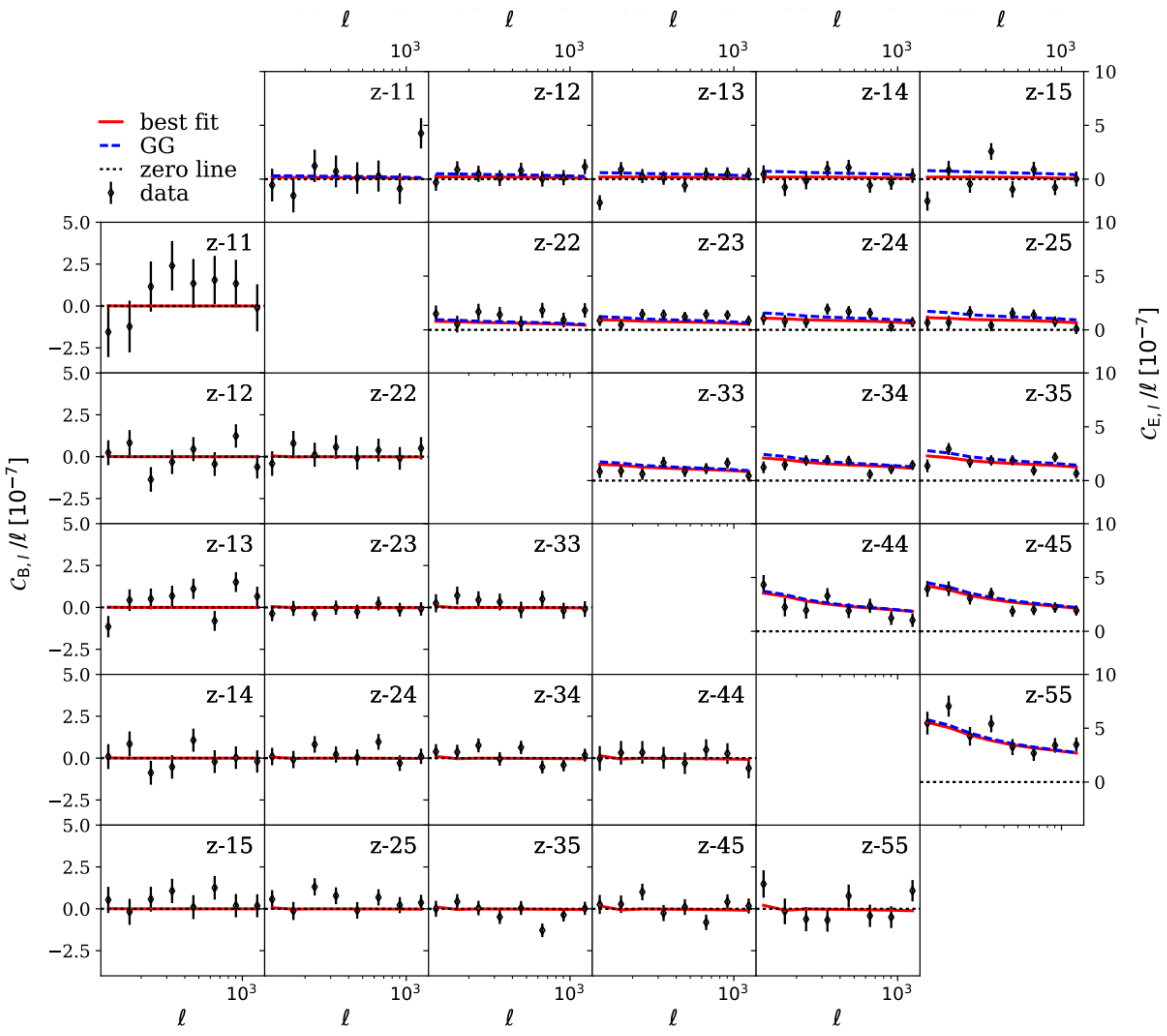

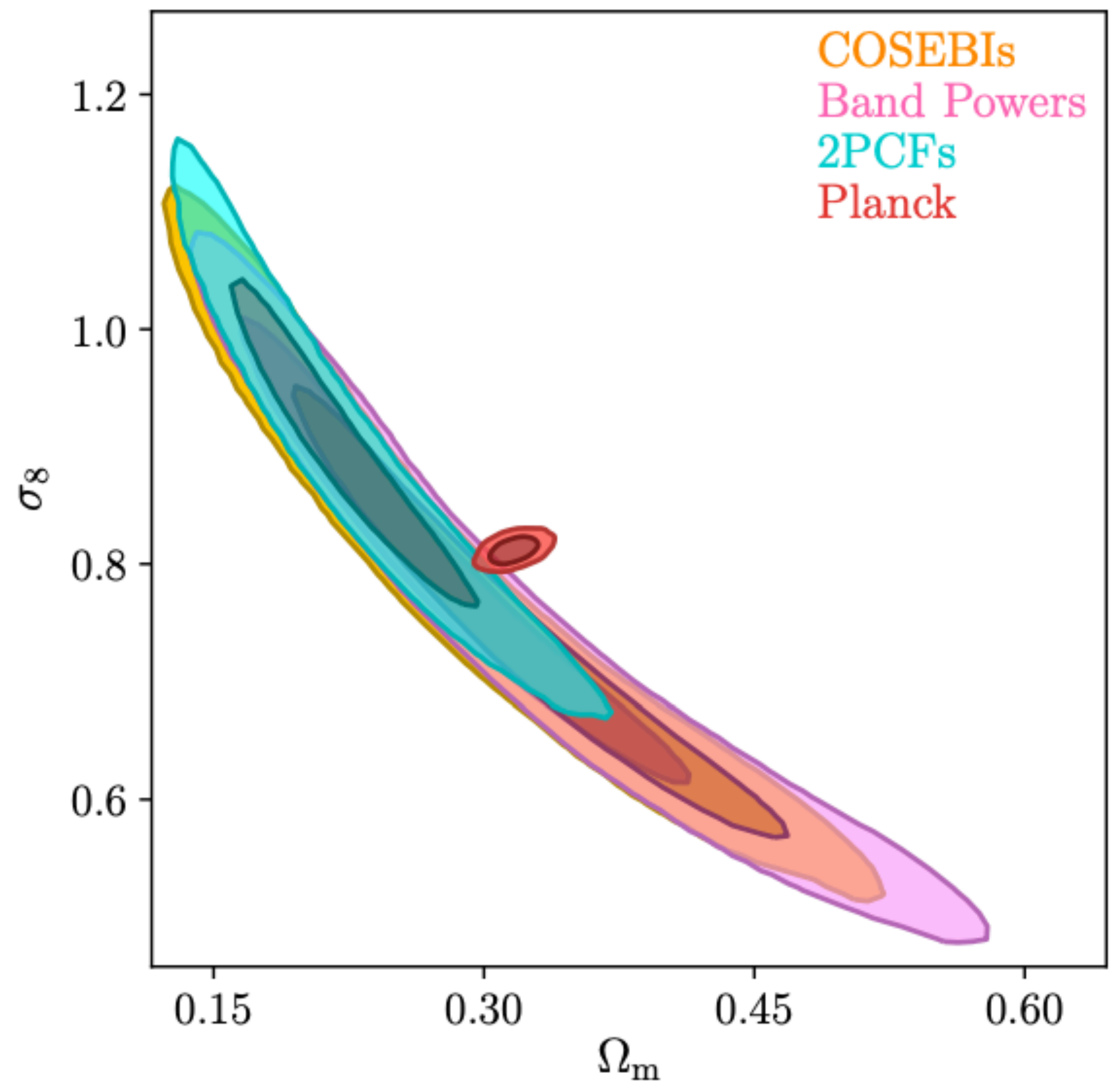

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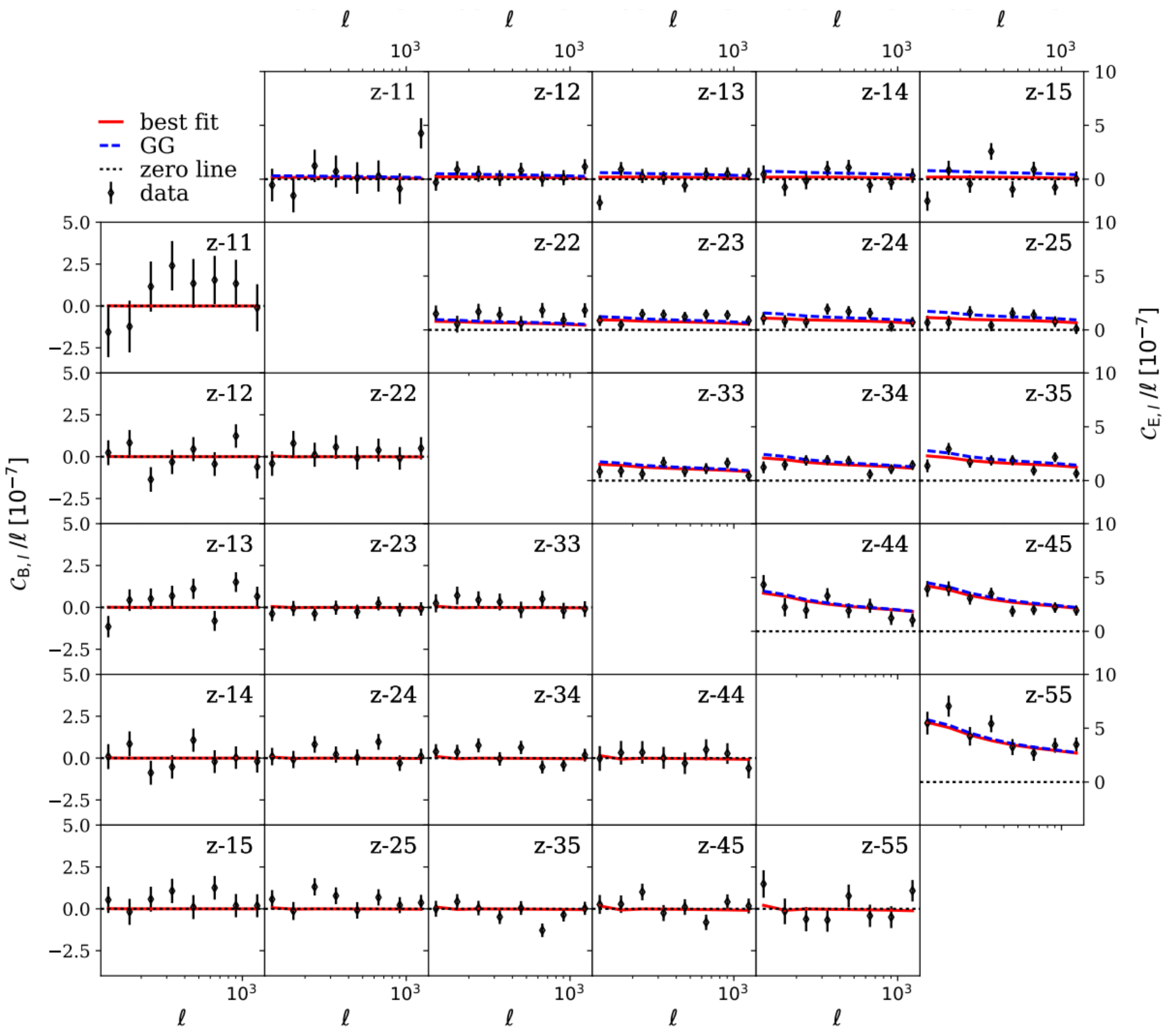

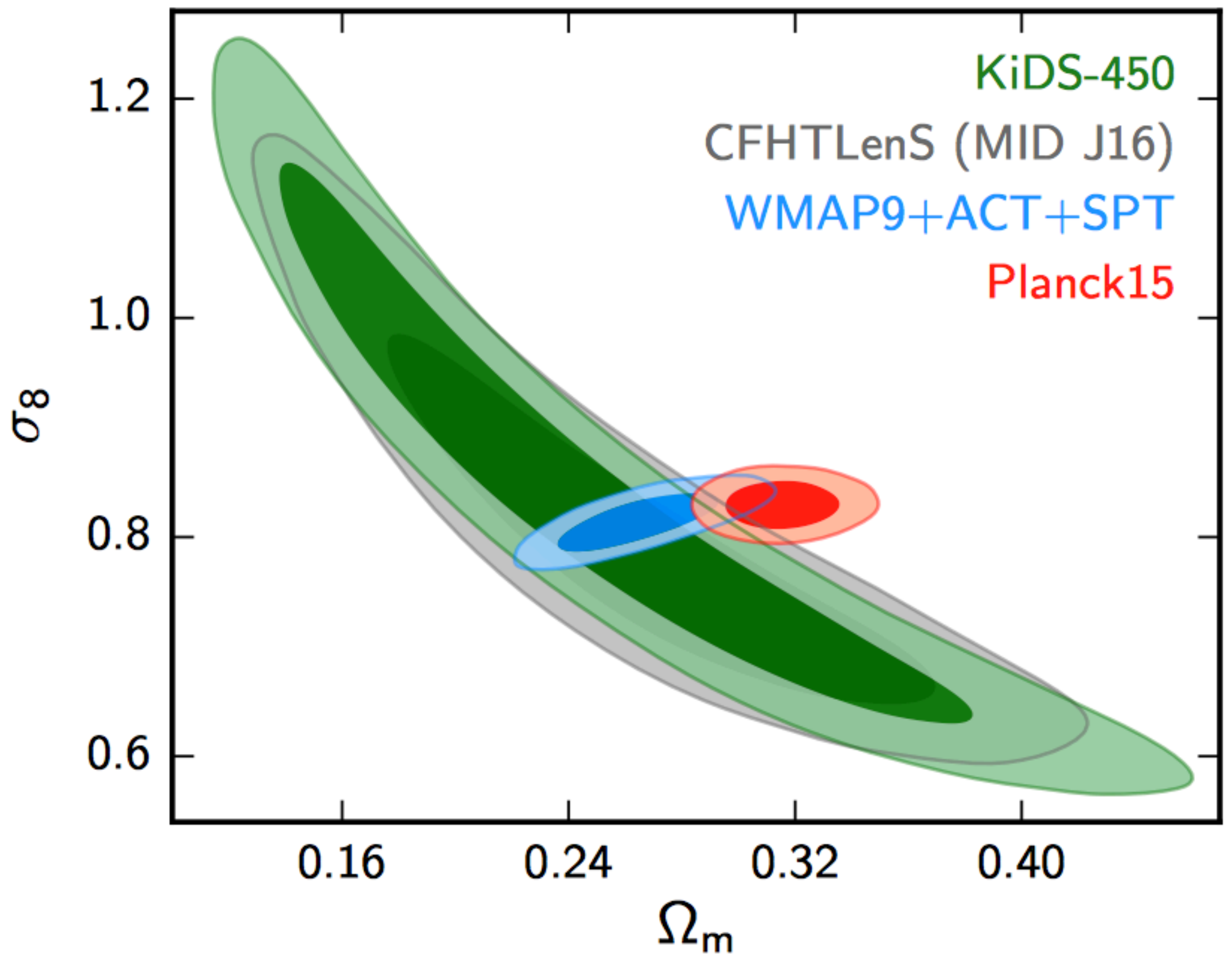

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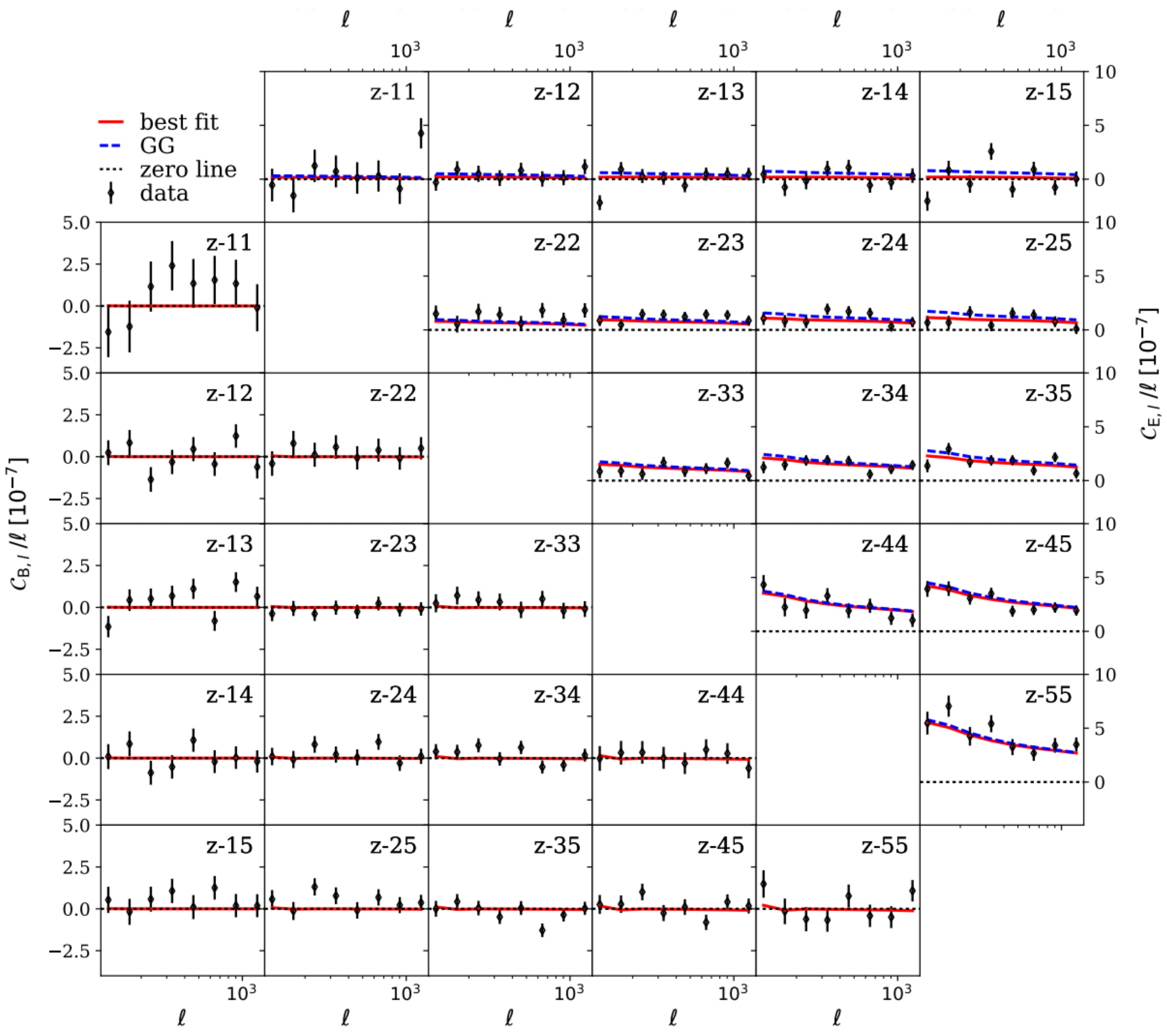

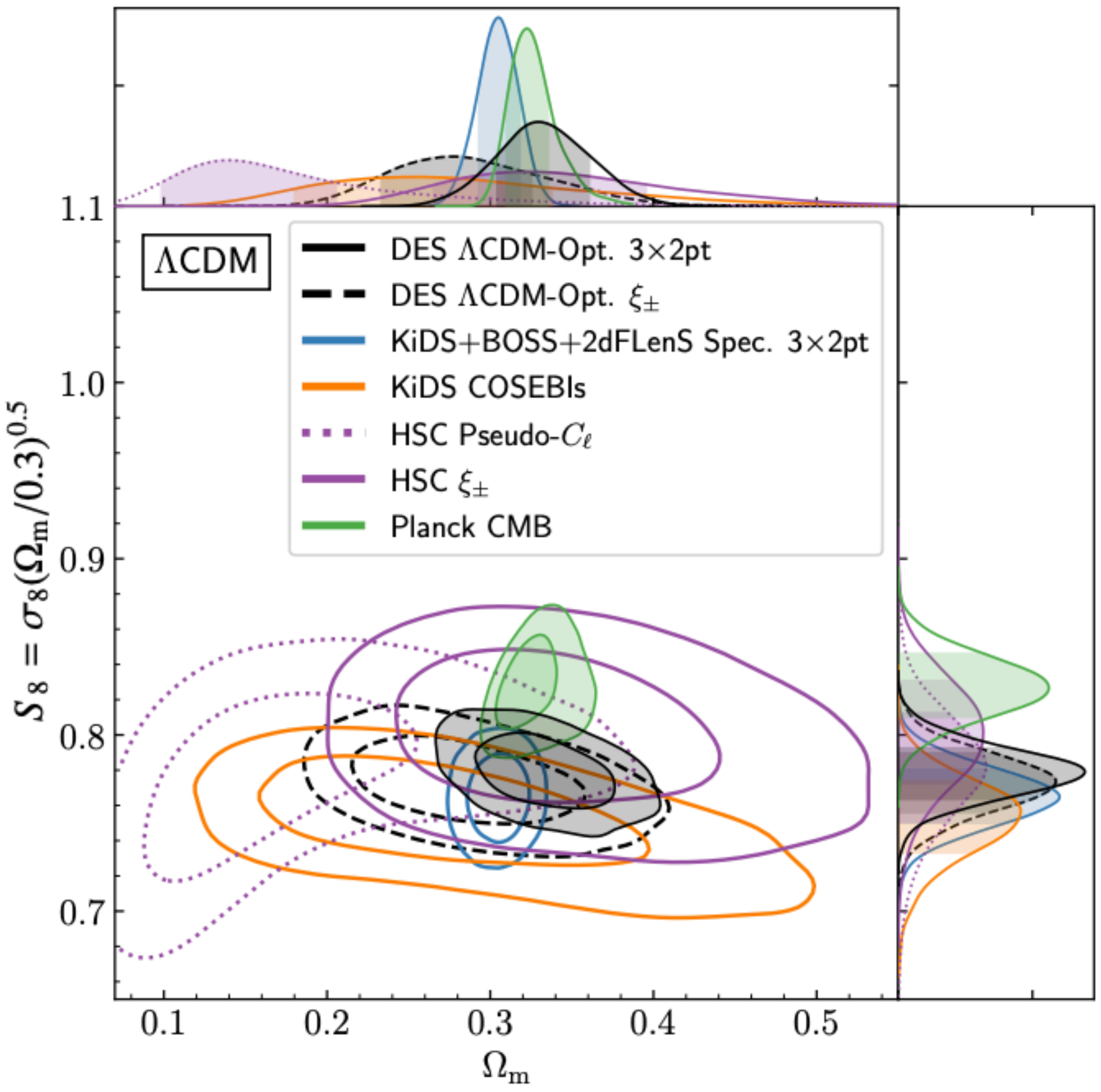

DES-Y3 - 2021

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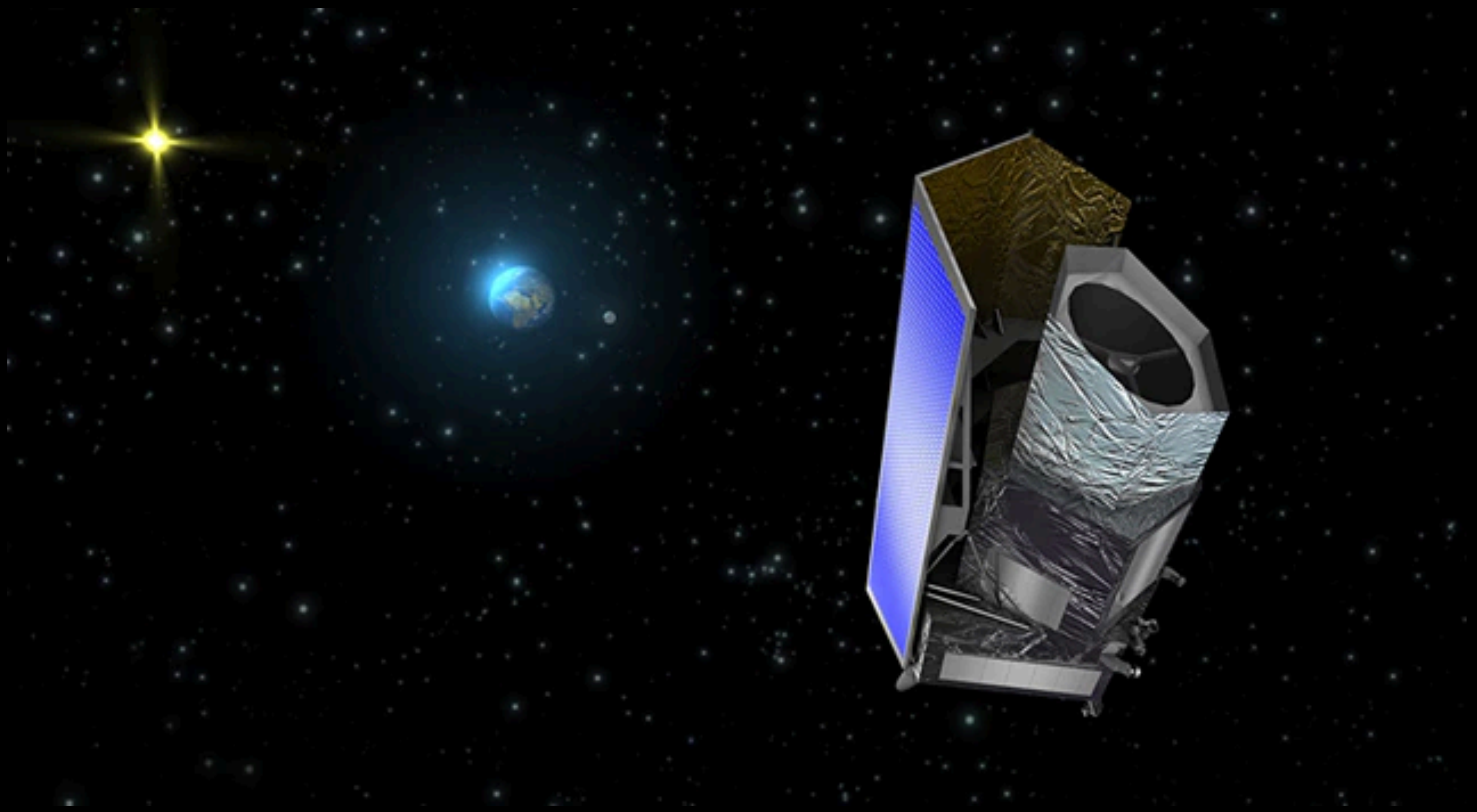
Wide field surveys from space

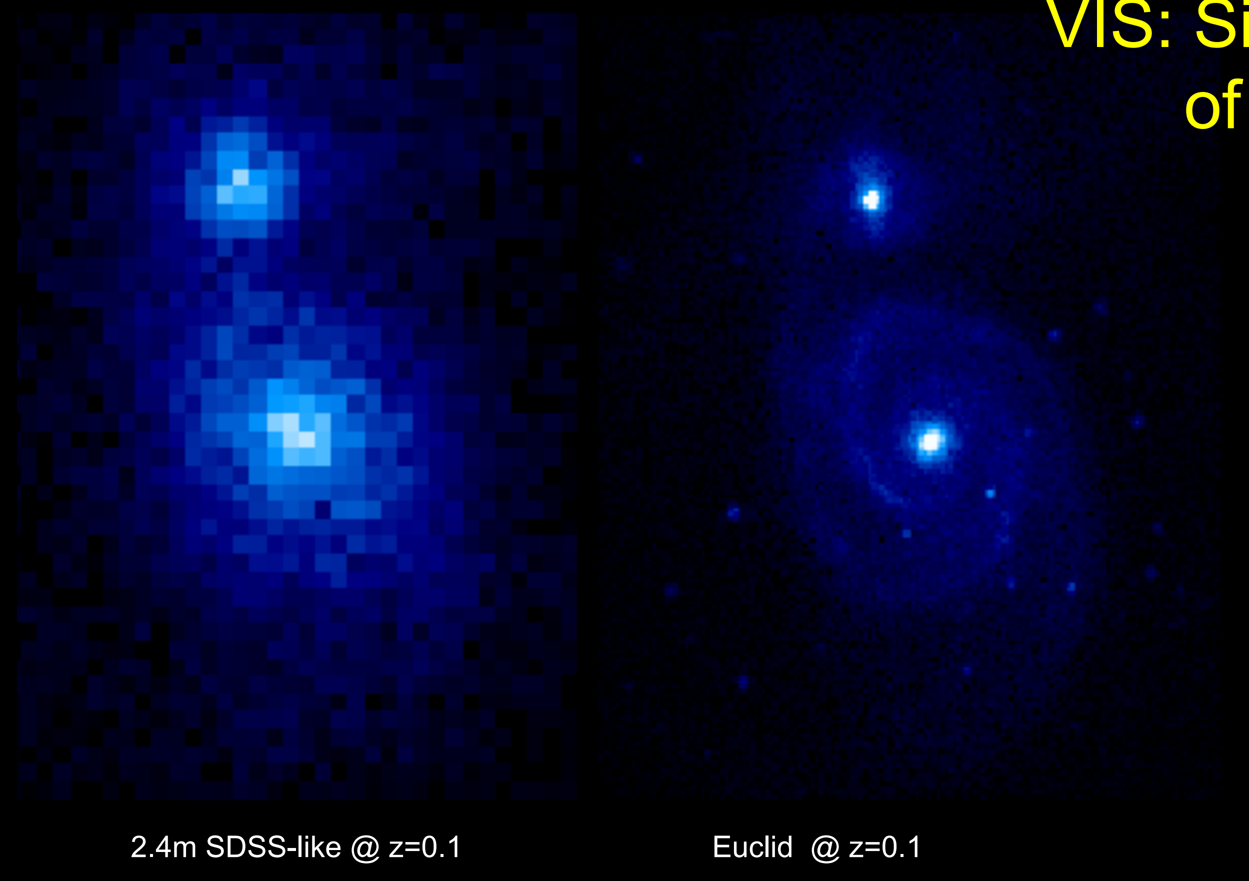


approximately 30 gal/arcmin^2
15.0000 deg^2
the peak of the source redshift distribution will move toward redshift z~1;
large sample of tomographic bins (10) for weak lensing analyses.

- improve cosmological constraints
- trace the growth of structures
- dark energy equation of state
- eventually look for new physics

Laureijs et al. 2011

VIS: Simulation of M51



Euclid will get the resolution of SDSS but at z=1 instead of z=0.05.
Euclid will be 3 magnitudes deeper → Euclid Legacy = Super-Sloan Survey

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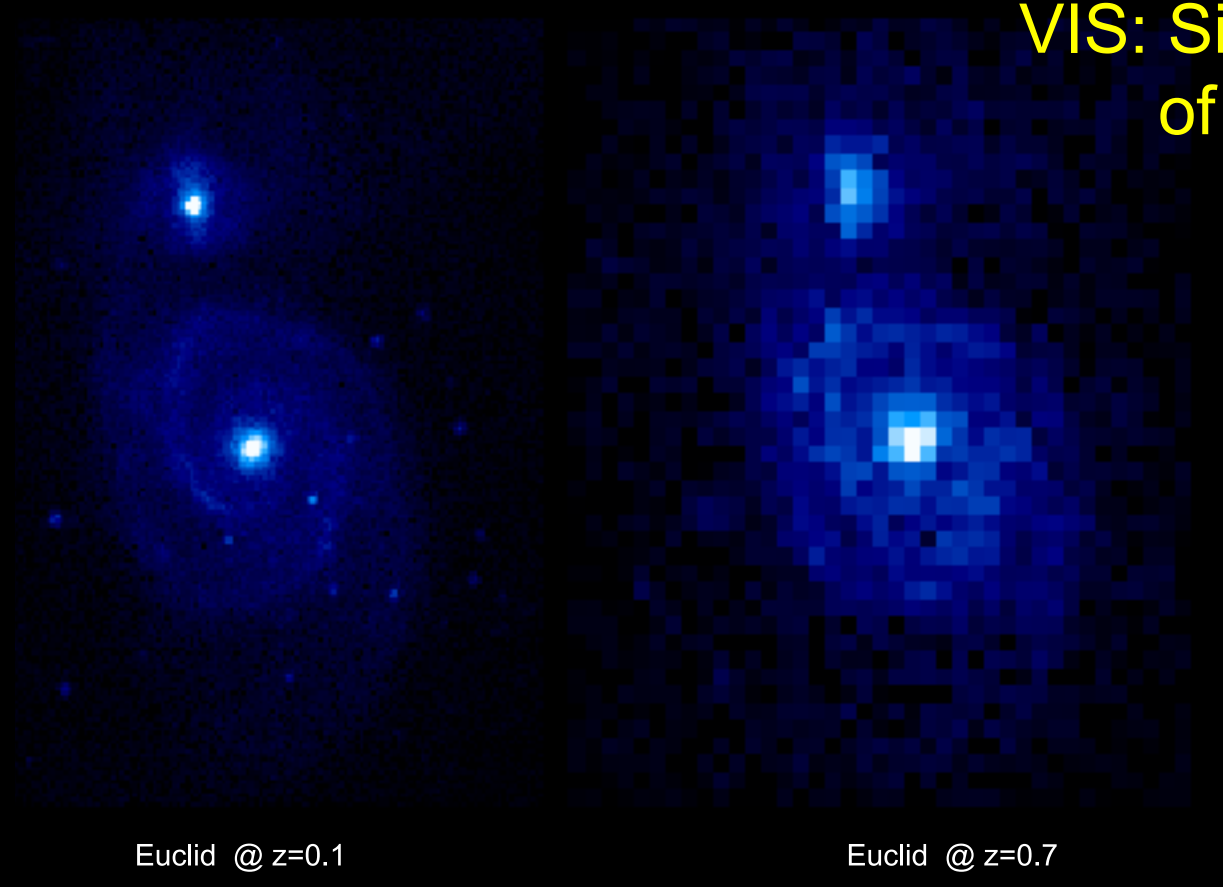

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courtesy of Miller

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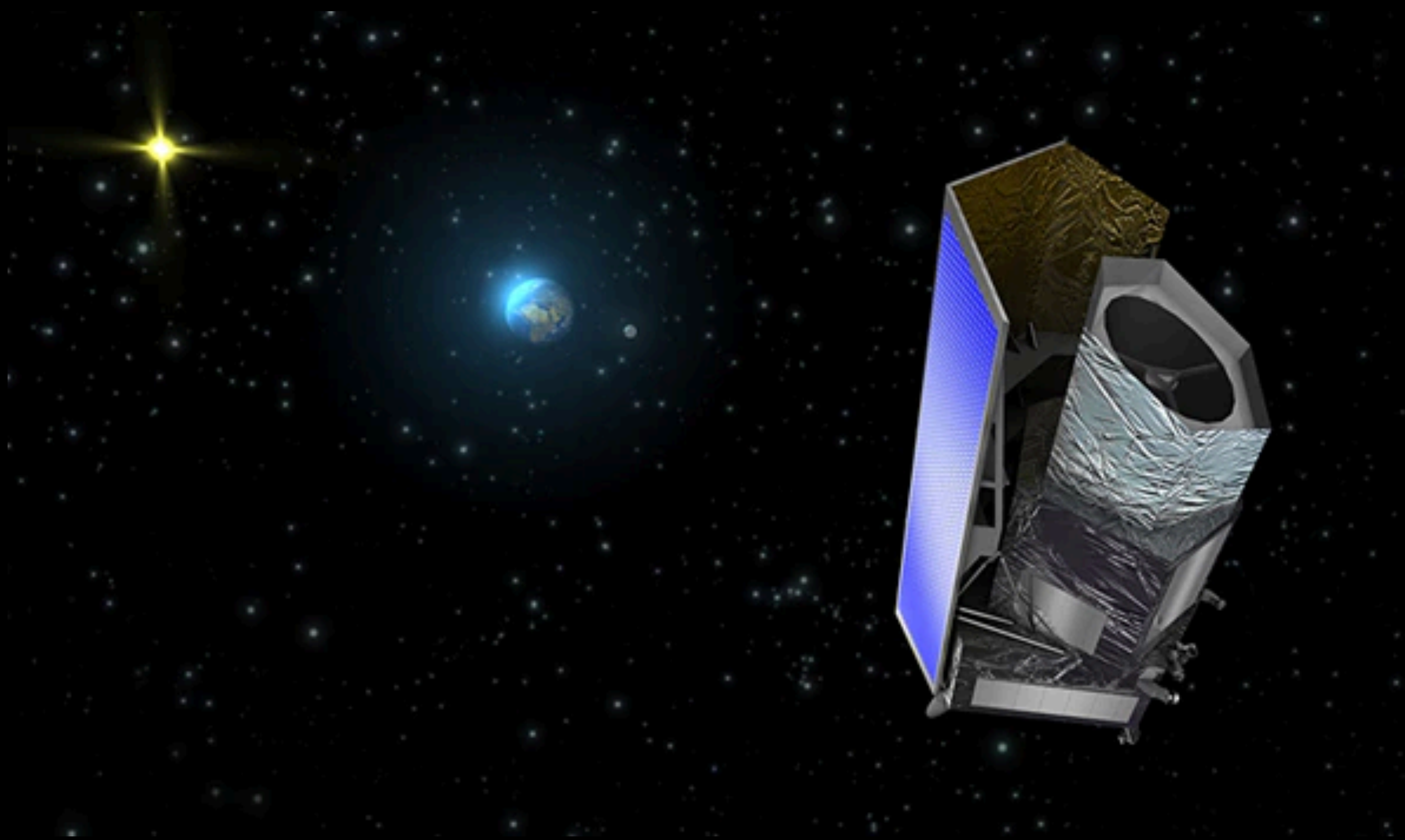

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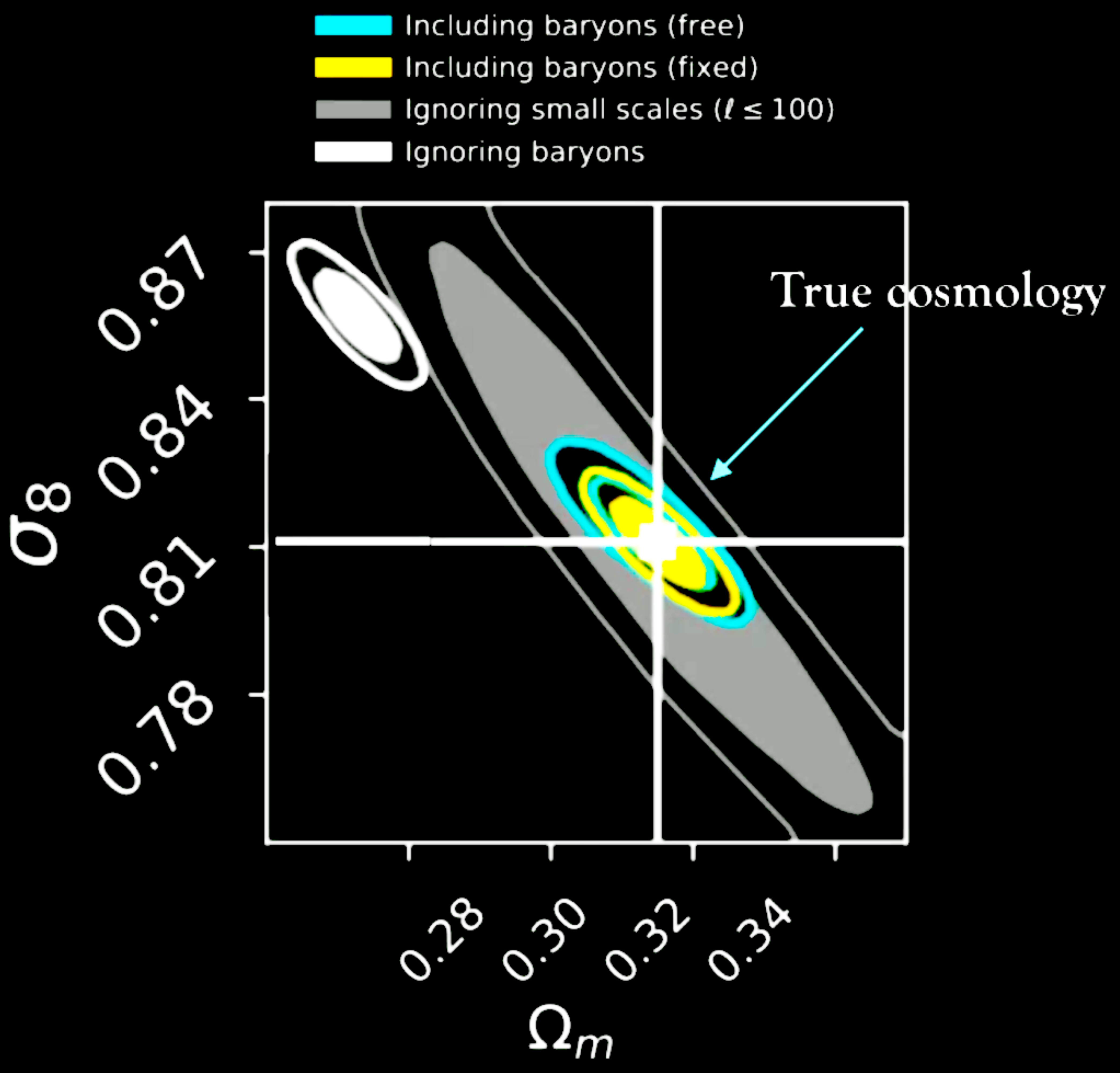

Forecasts by A. Schneider et al (2020)

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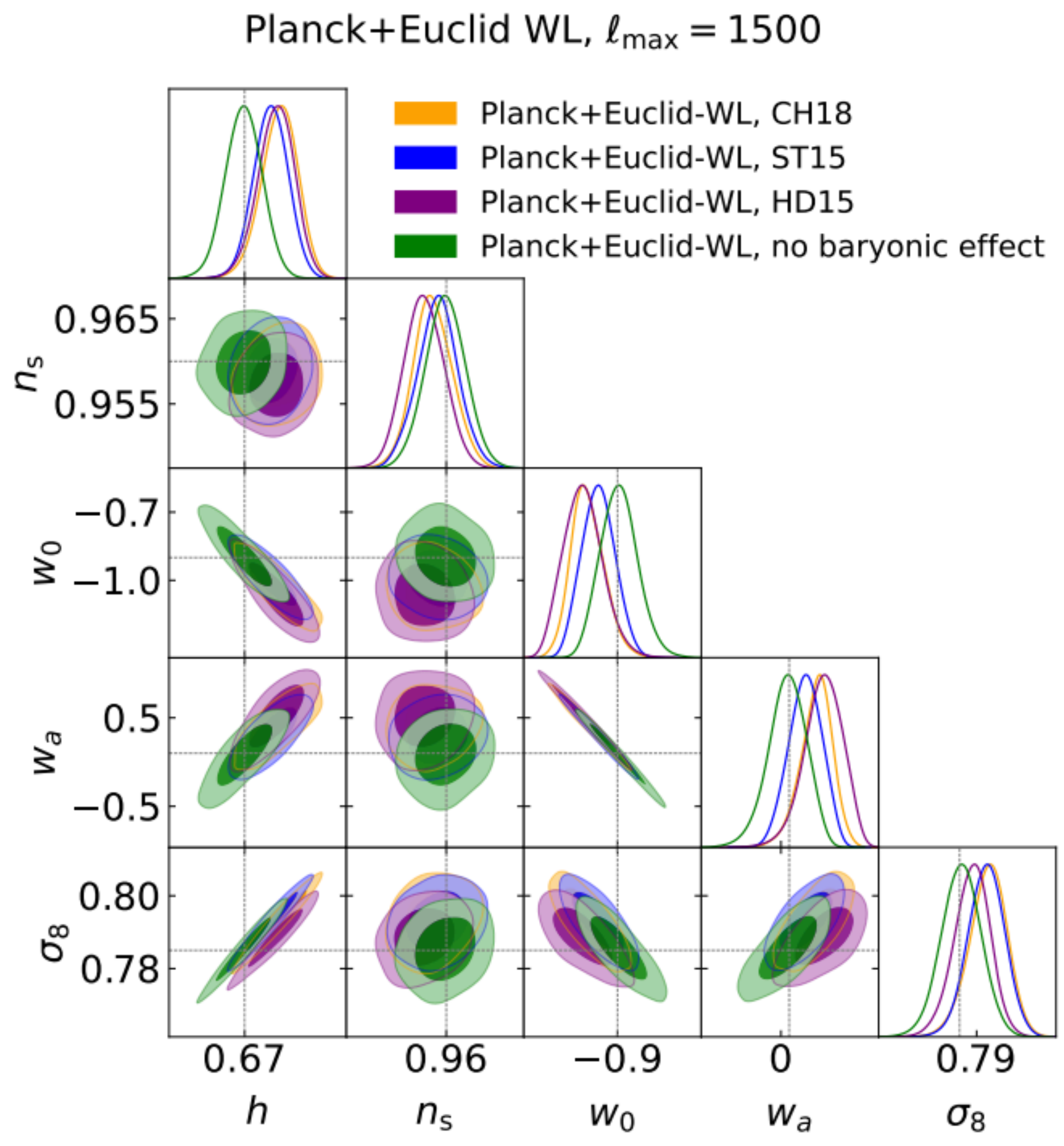

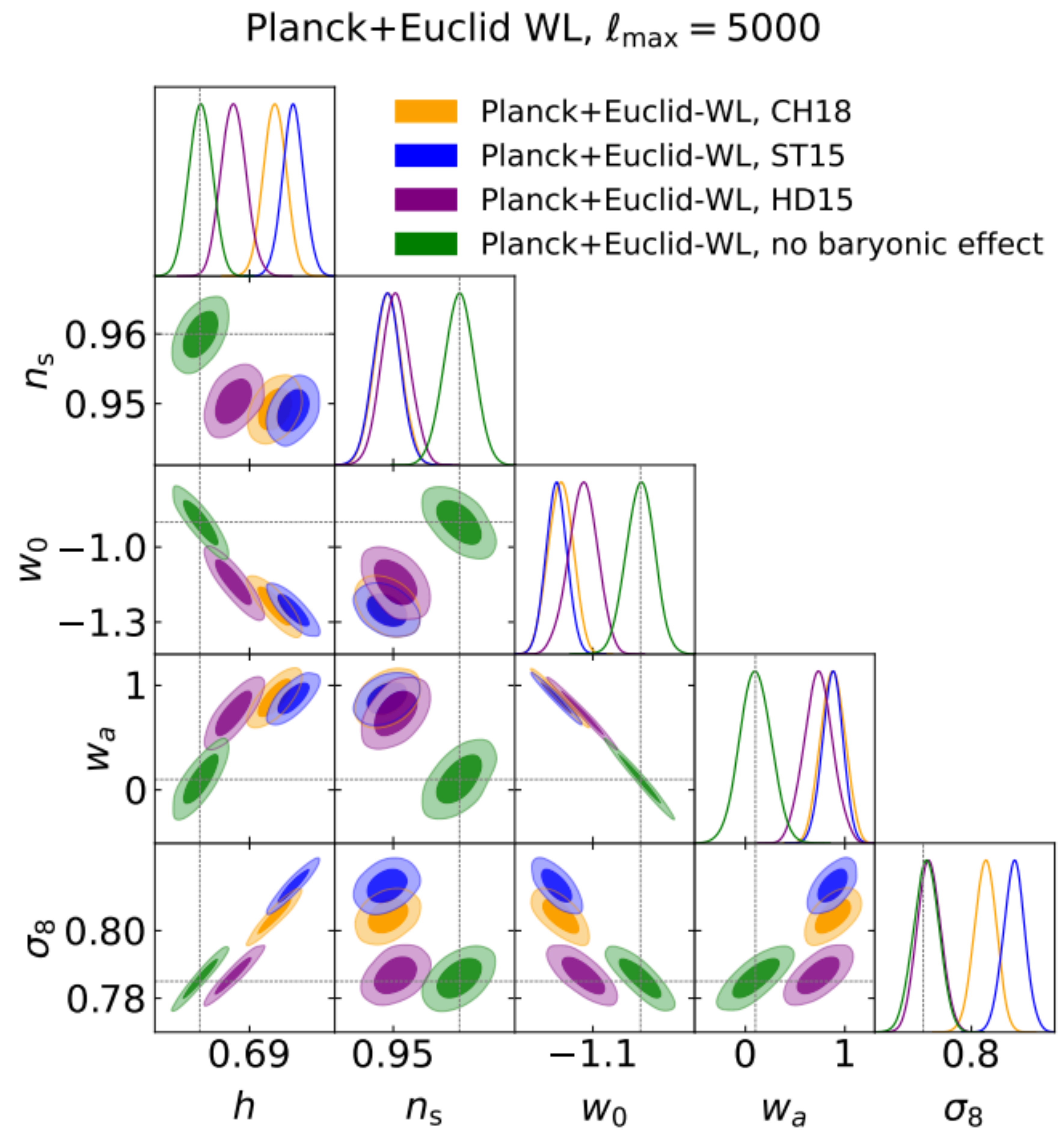

Reference model: Halofit+PKequal

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(Euclid) Martinelli et al. (incl. Giocoli) 2021

IST:nonlinear

Martin Crocce

Carlo Giocoli

Alkistis Pourtsidou

Convergence power spectrum

from linear to non-linear theory

Full cosmological exploitation of observational data we need

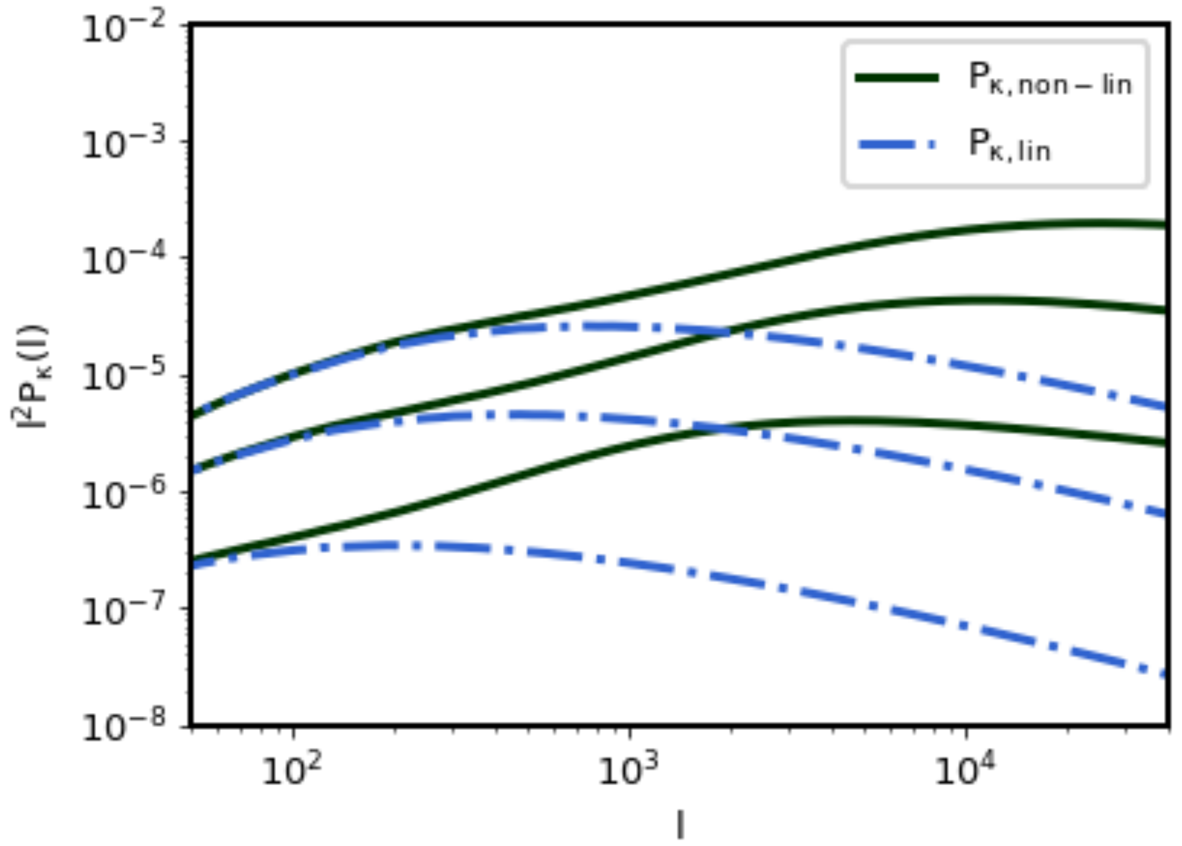
Theoretical models for the non-linear power spectrum

in the Limber and Born approximation regimes and sources at a given redshift z_s:

$$P_\kappa(l) = \frac{9H_0^4\Omega_m^2}{4c^4}\int_0^{w_s} \mathrm{d}w \left(\frac{D(z,z_s)}{D(z_s)a(z)}\right)^2 P_\delta\left(l\frac{a(z)}{D(z)}, z\right)$$

2D

3D non-linear



for the three-dimensional matter power spectrum:

- Models (Halofit and extended versions)
- Perturbation theory
- Halo Model & extended versions

- accurate numerical simulations (with baryons, beyond the standard model etc.) based on N-Body solvers
- approximate methods (COLA, Pinocchio, Patchy ...)

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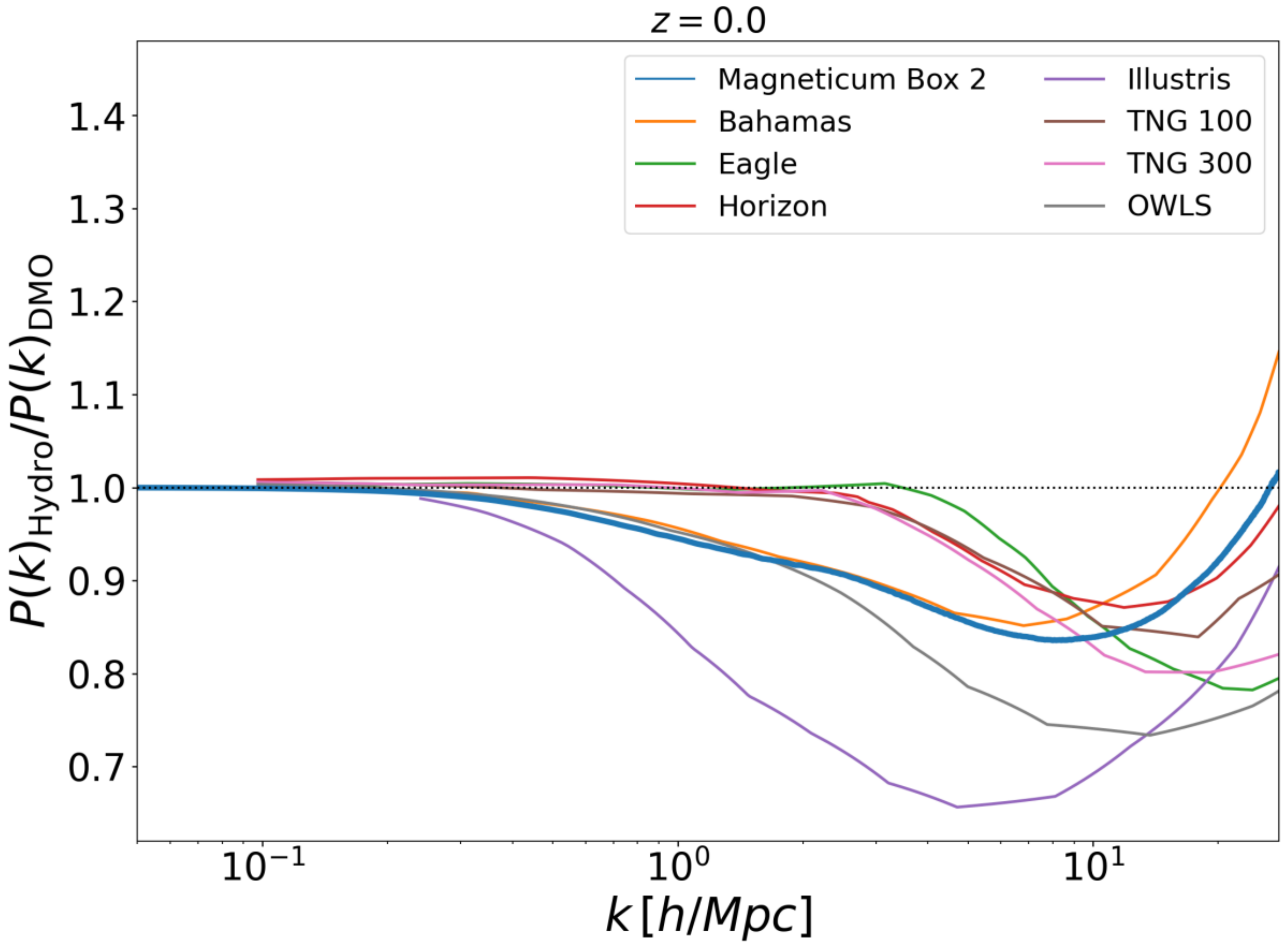
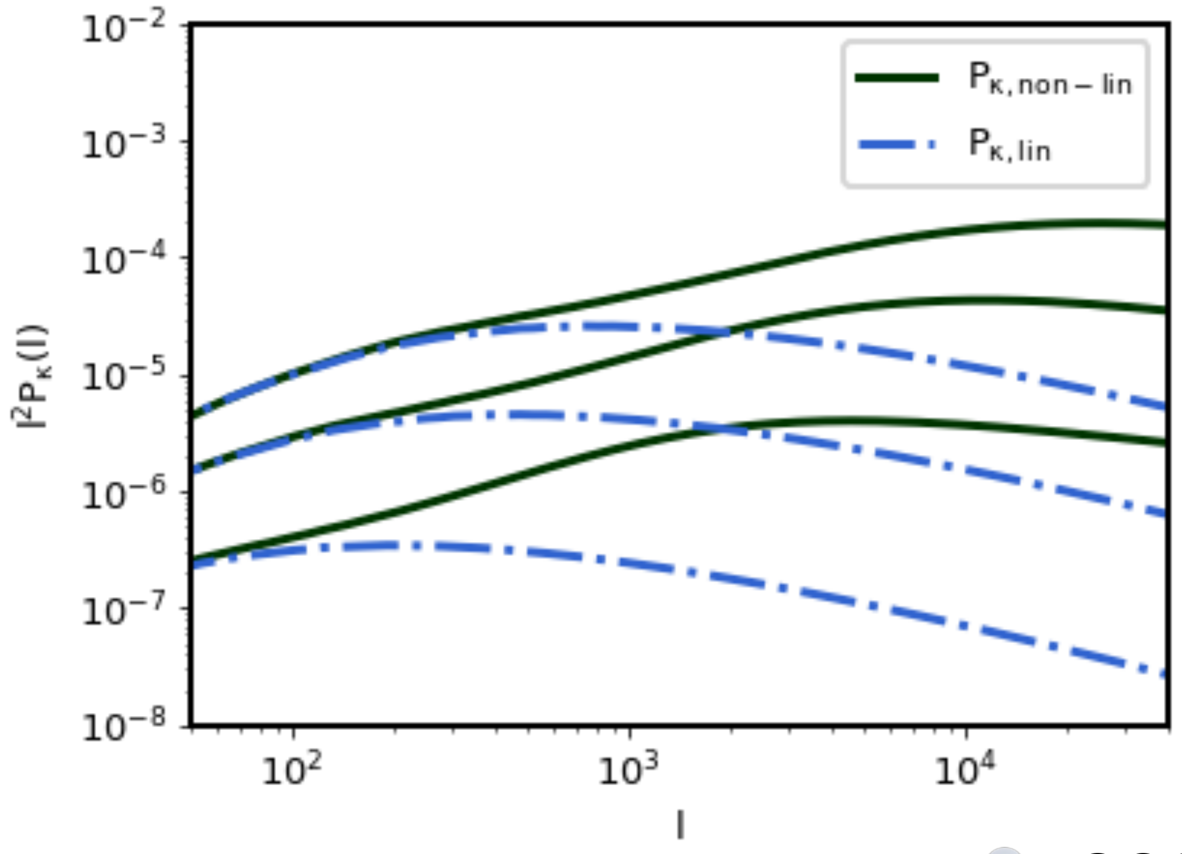


Martinet et al. (incl. Giocoli) 2021



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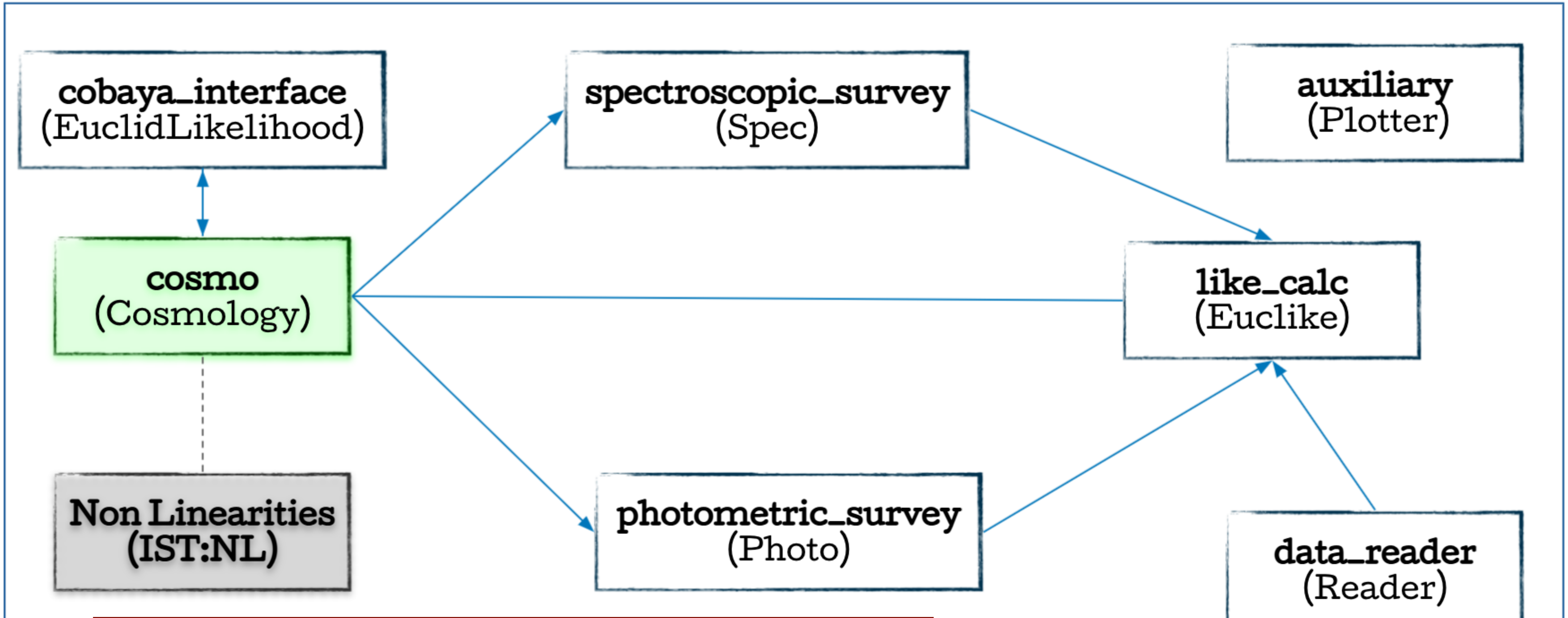
Cosmology Likelihood for Observables in Euclid

Structure of CLOE



Validations and Benchmarks with dedicated simulations
Strong interface with Theory, Cosmological Simulation SWG and Galaxy Clusters

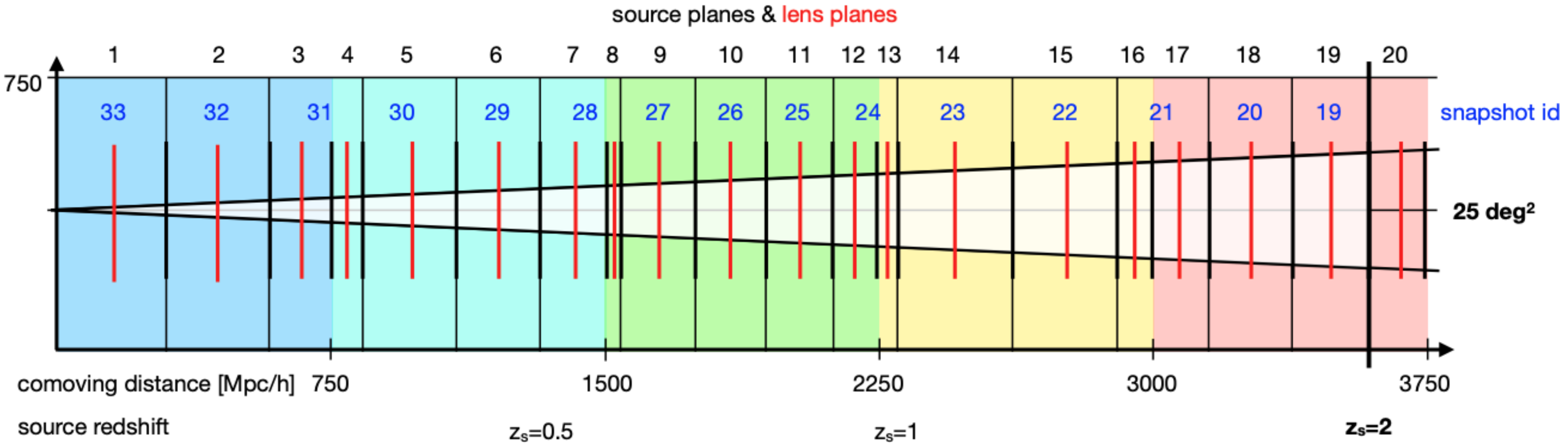
Curtesy of **Guadalupe Cañas-Herrera**

Building the Planes

MapSim

The mass density is then interpolated from the projected particle positions to a two-dimensional grid using a triangular shaped cloud (TSC) scheme.

Each colored box has a different randomization: box centre, sign of the axes and face of box in front of the observer.



Boyle et al. (incl. Giocoli) 2020 (box: 750 Mpc/h)

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Weak Gravitational Lensing

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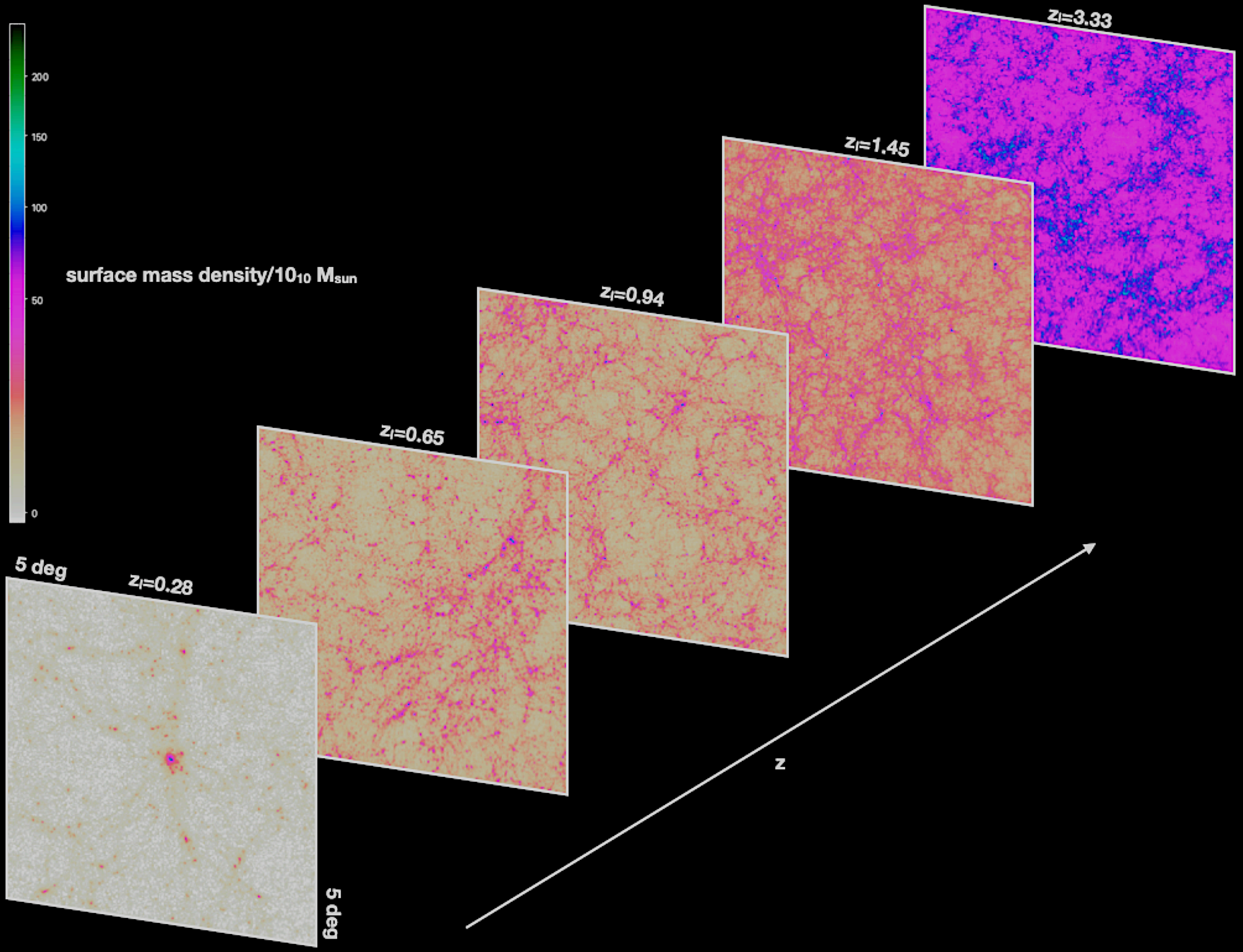

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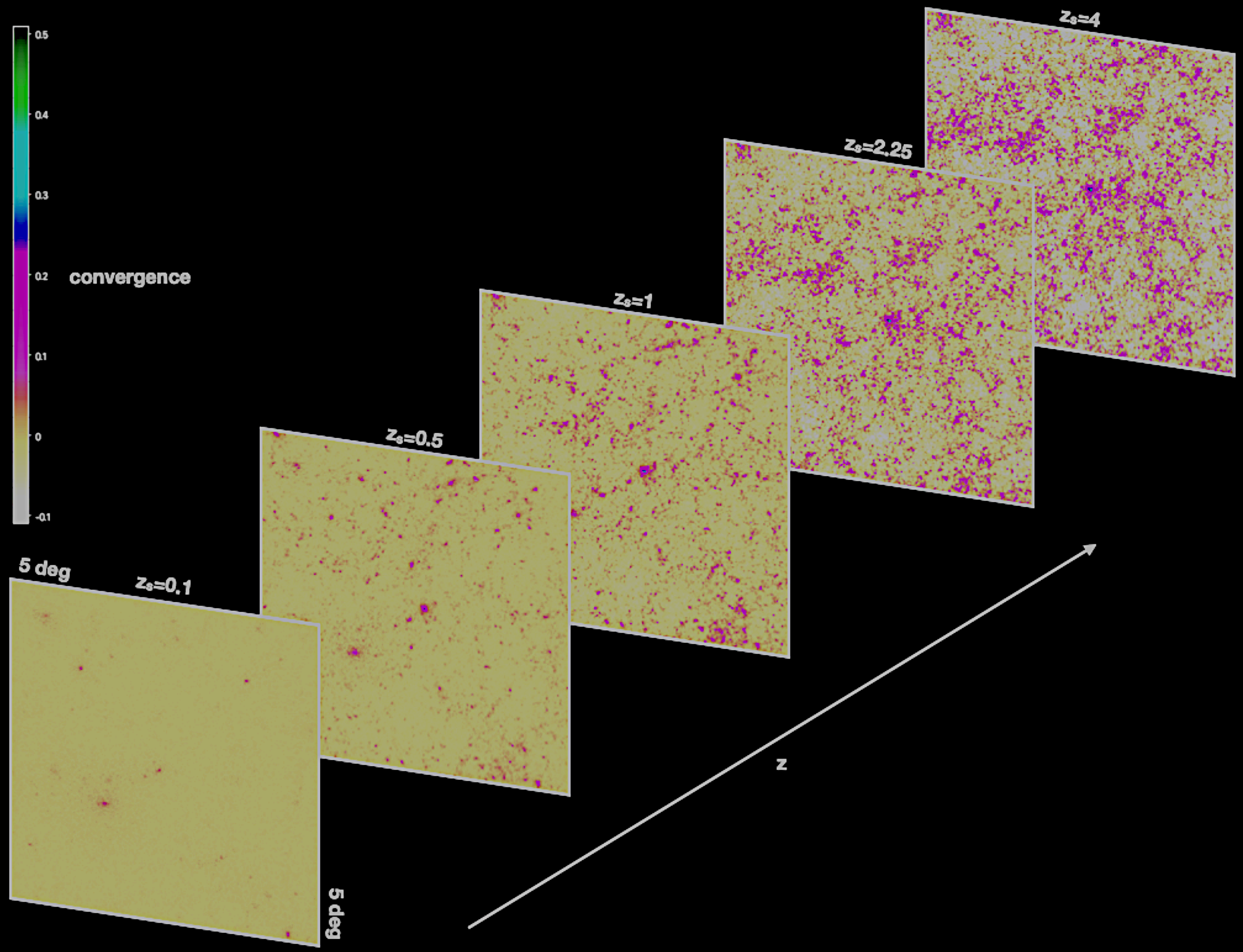

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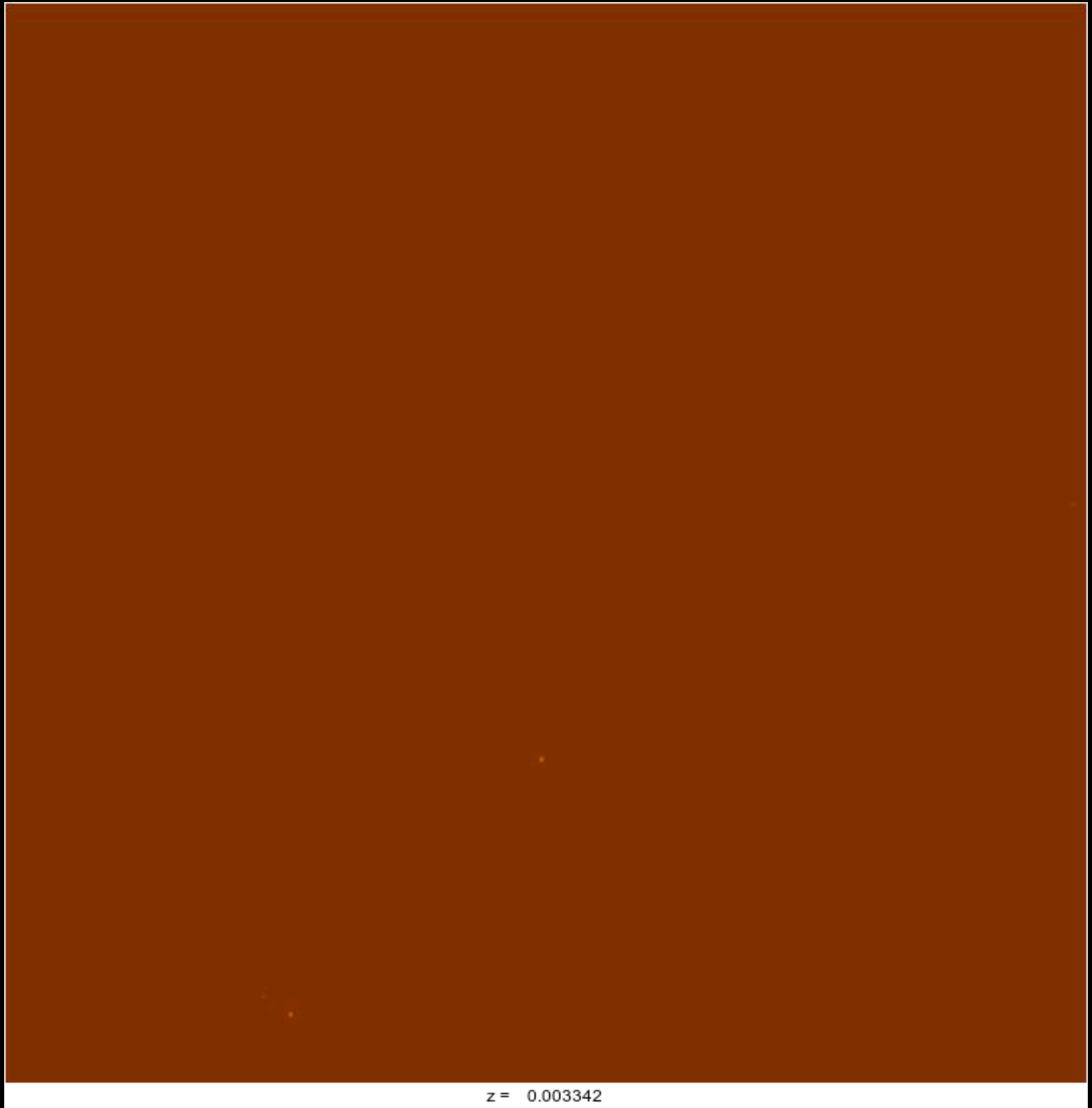
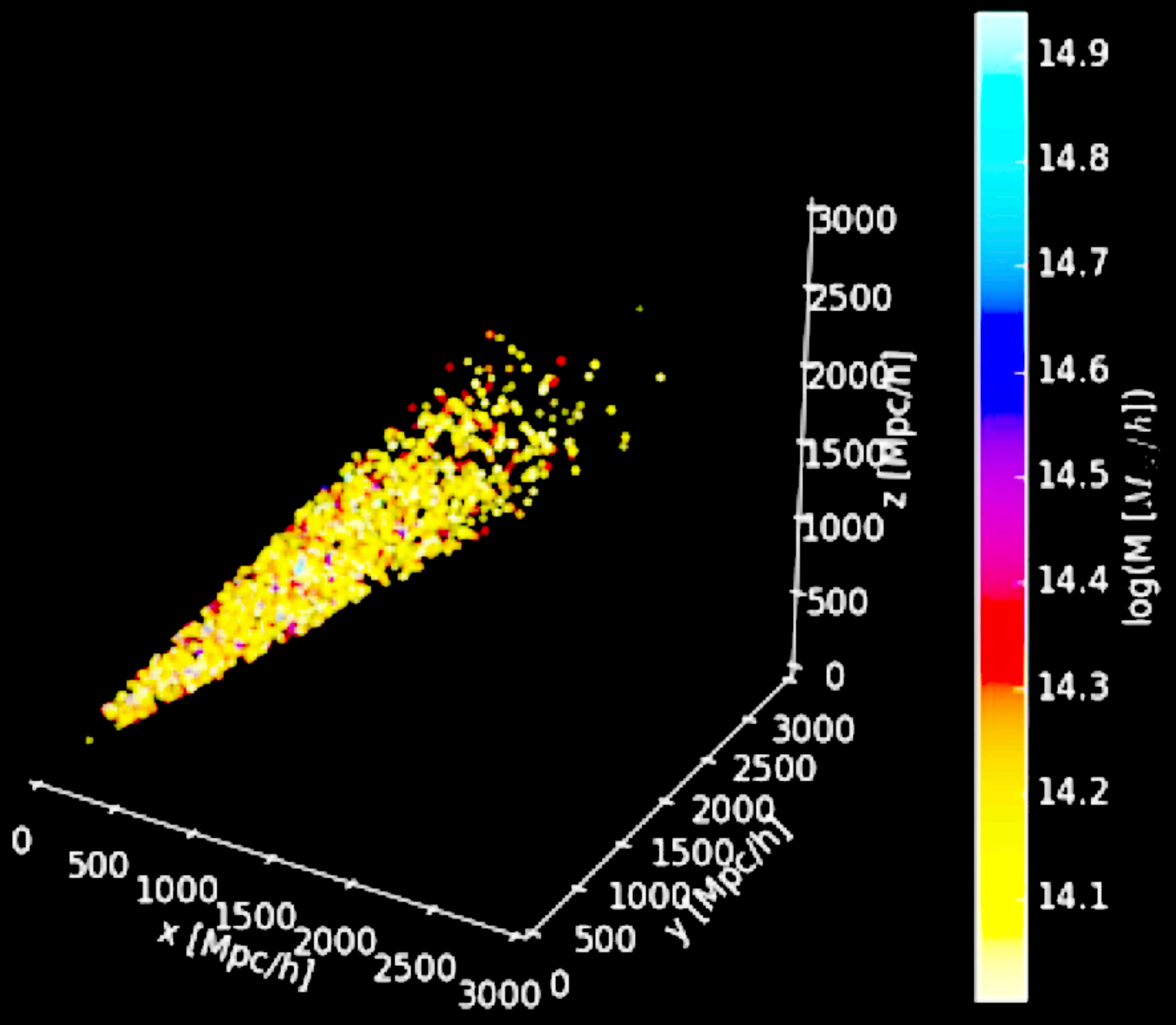
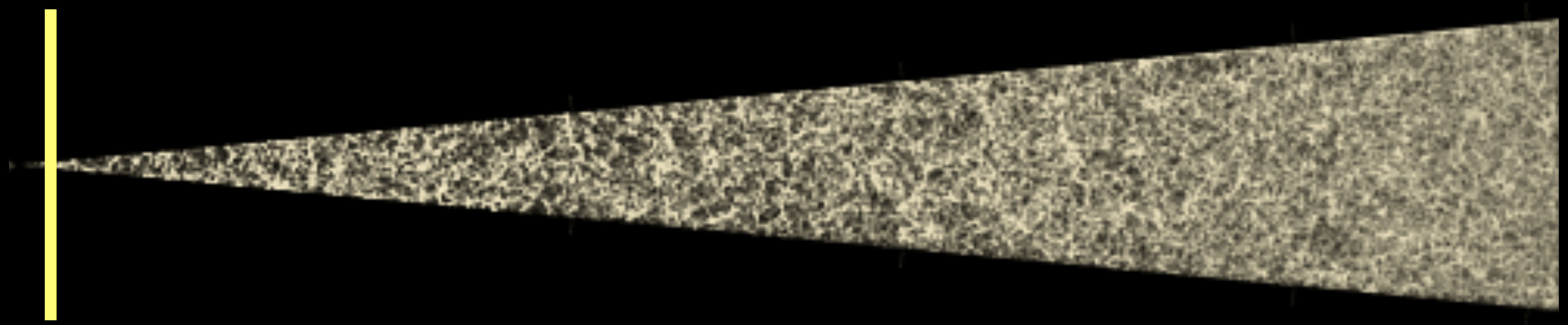
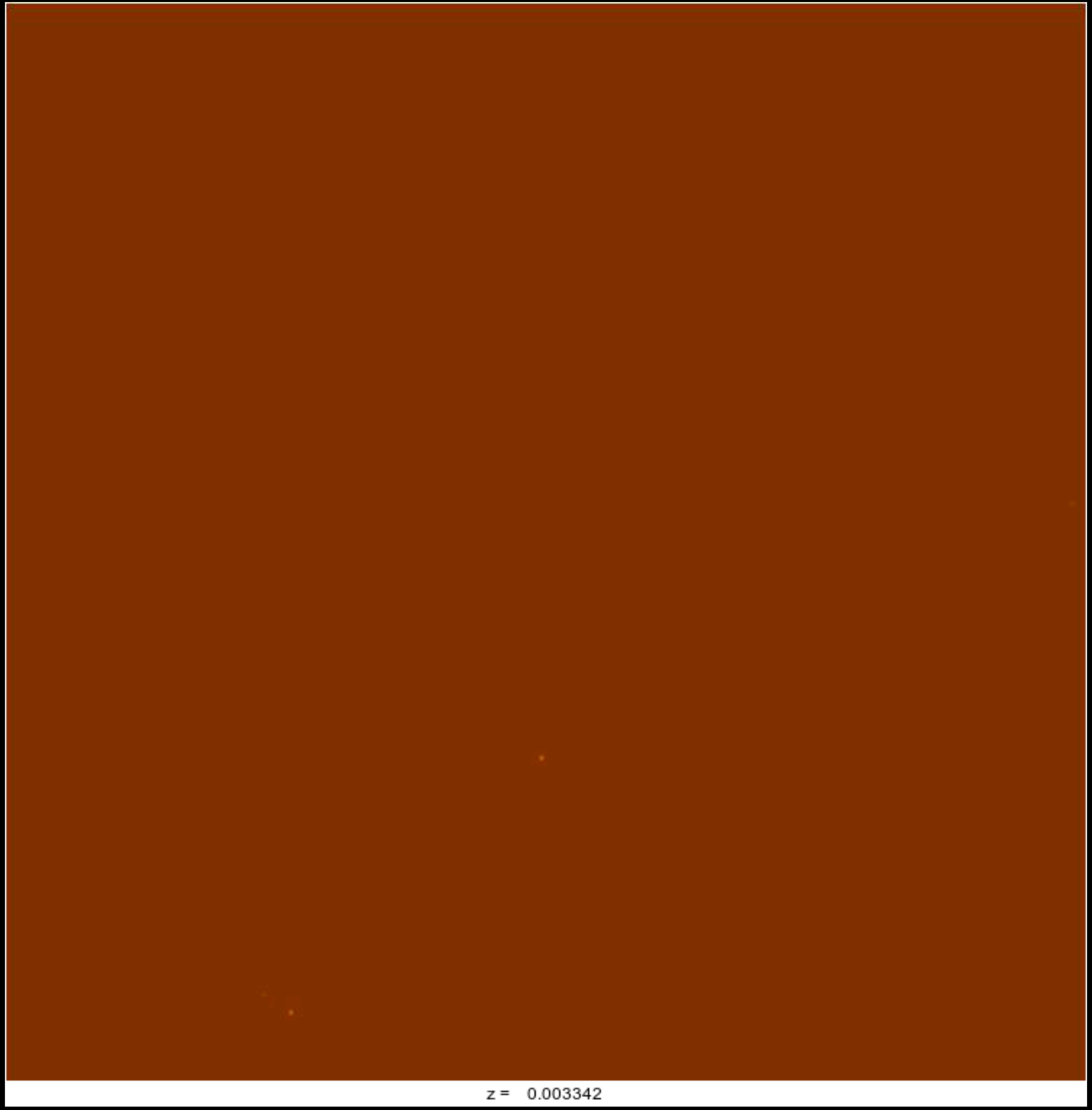


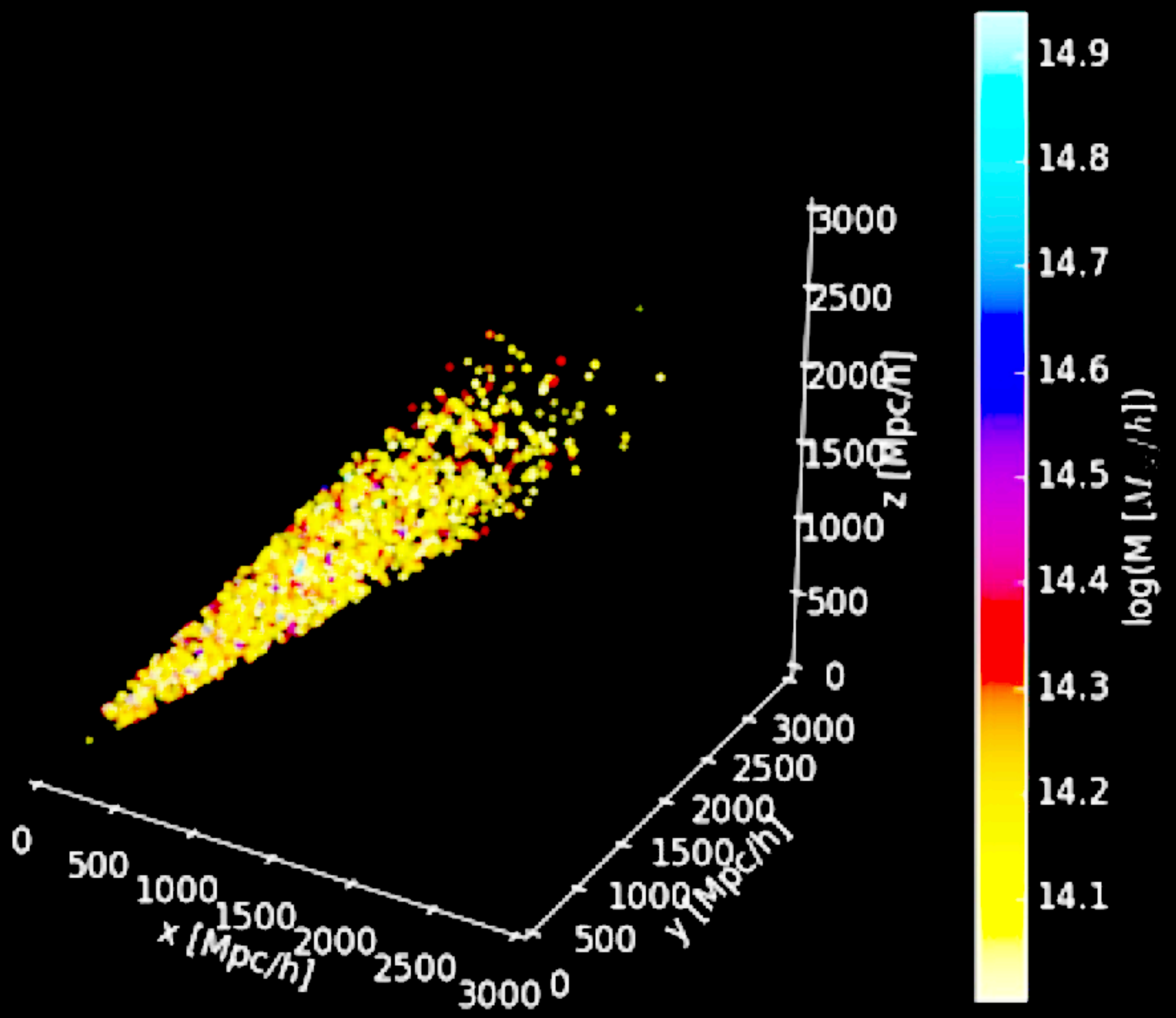


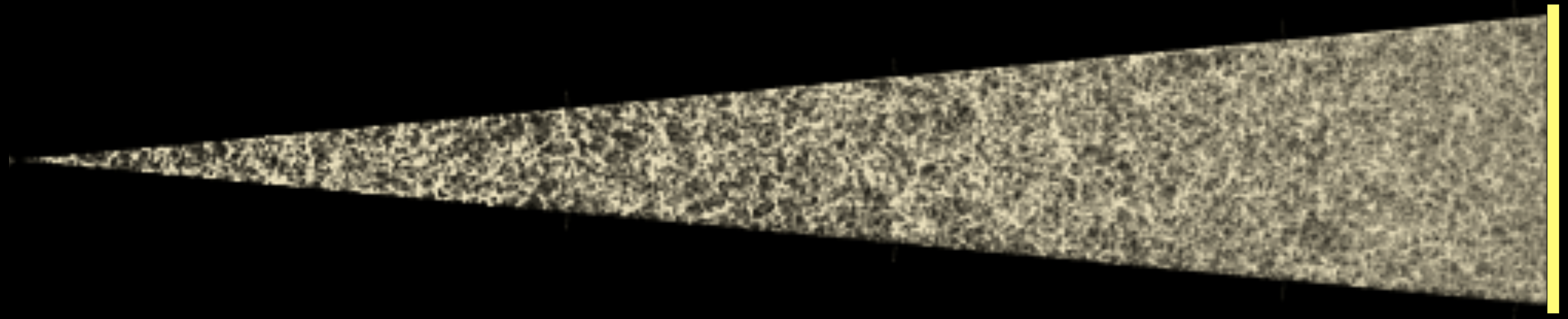


MapSim

Giocoli et al. 2015







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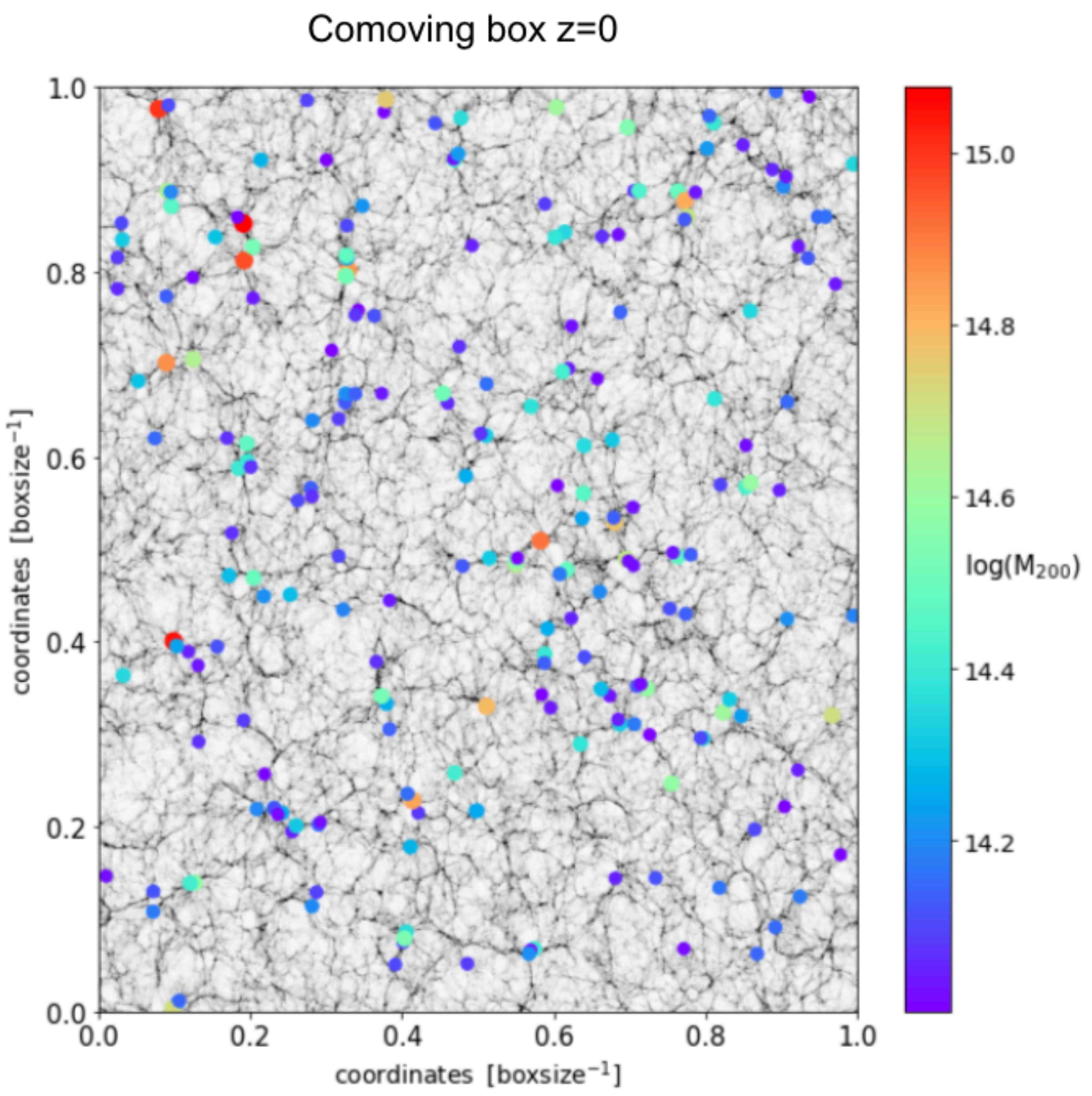

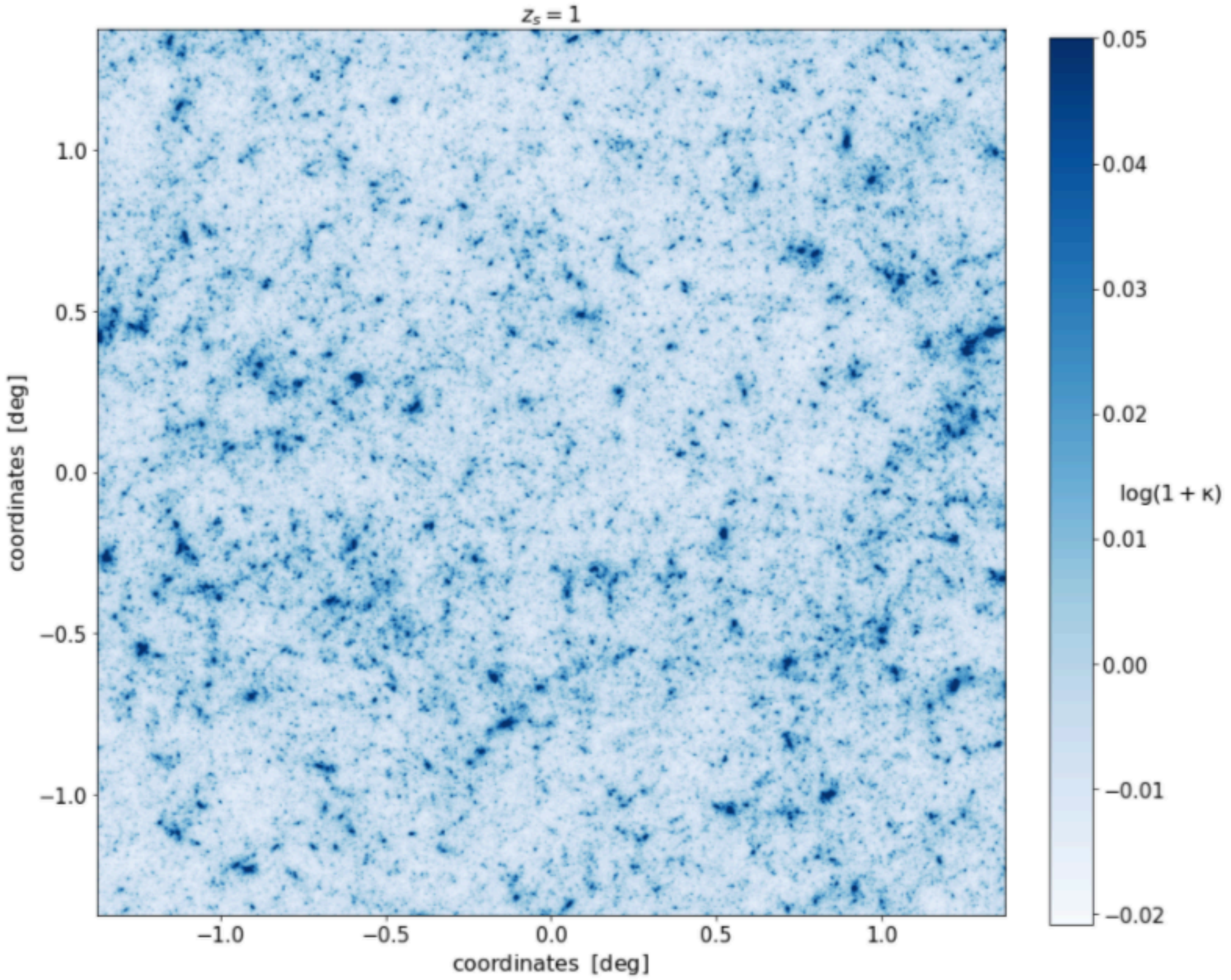

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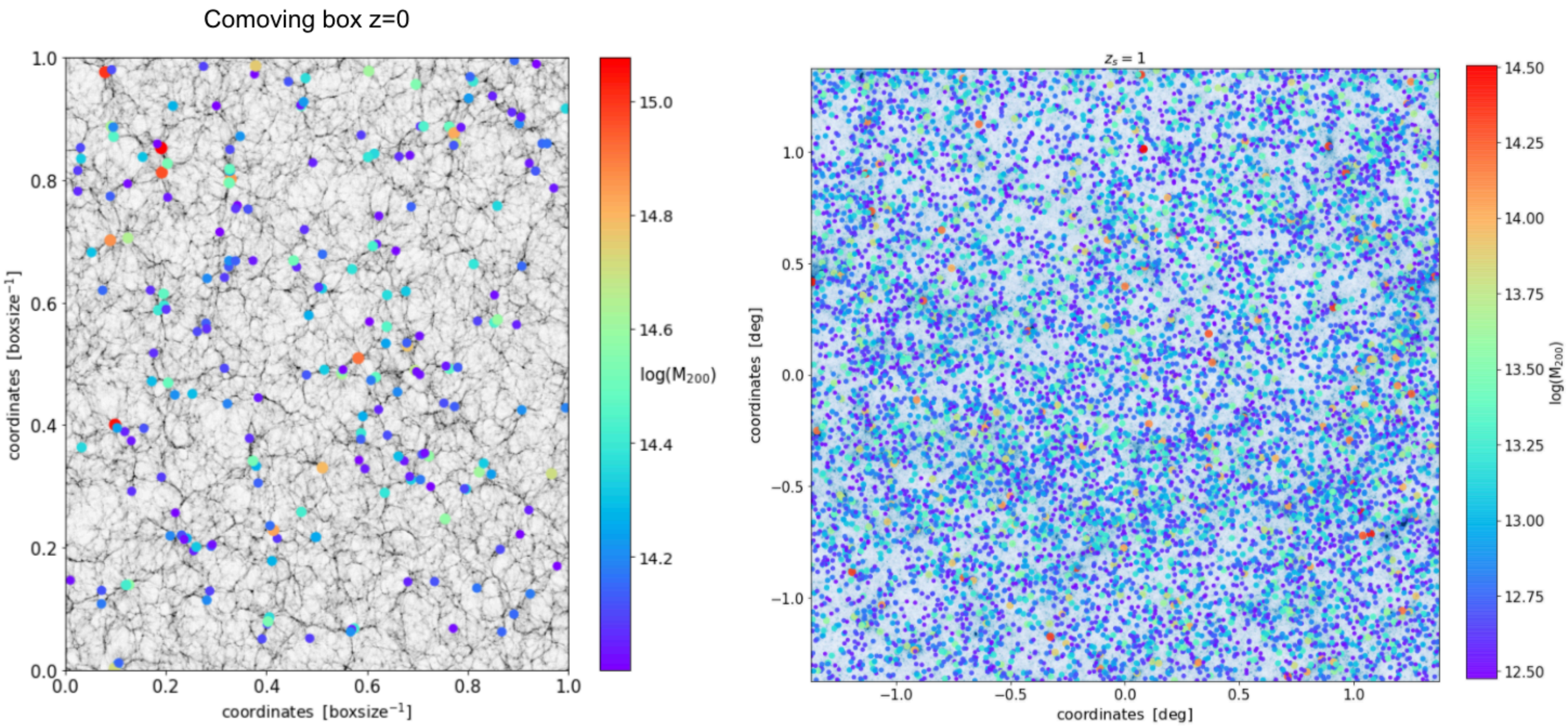
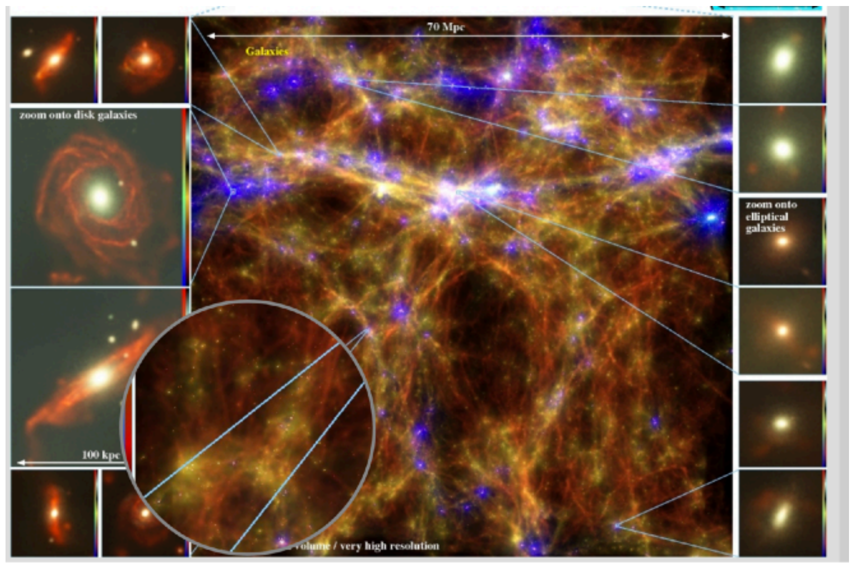
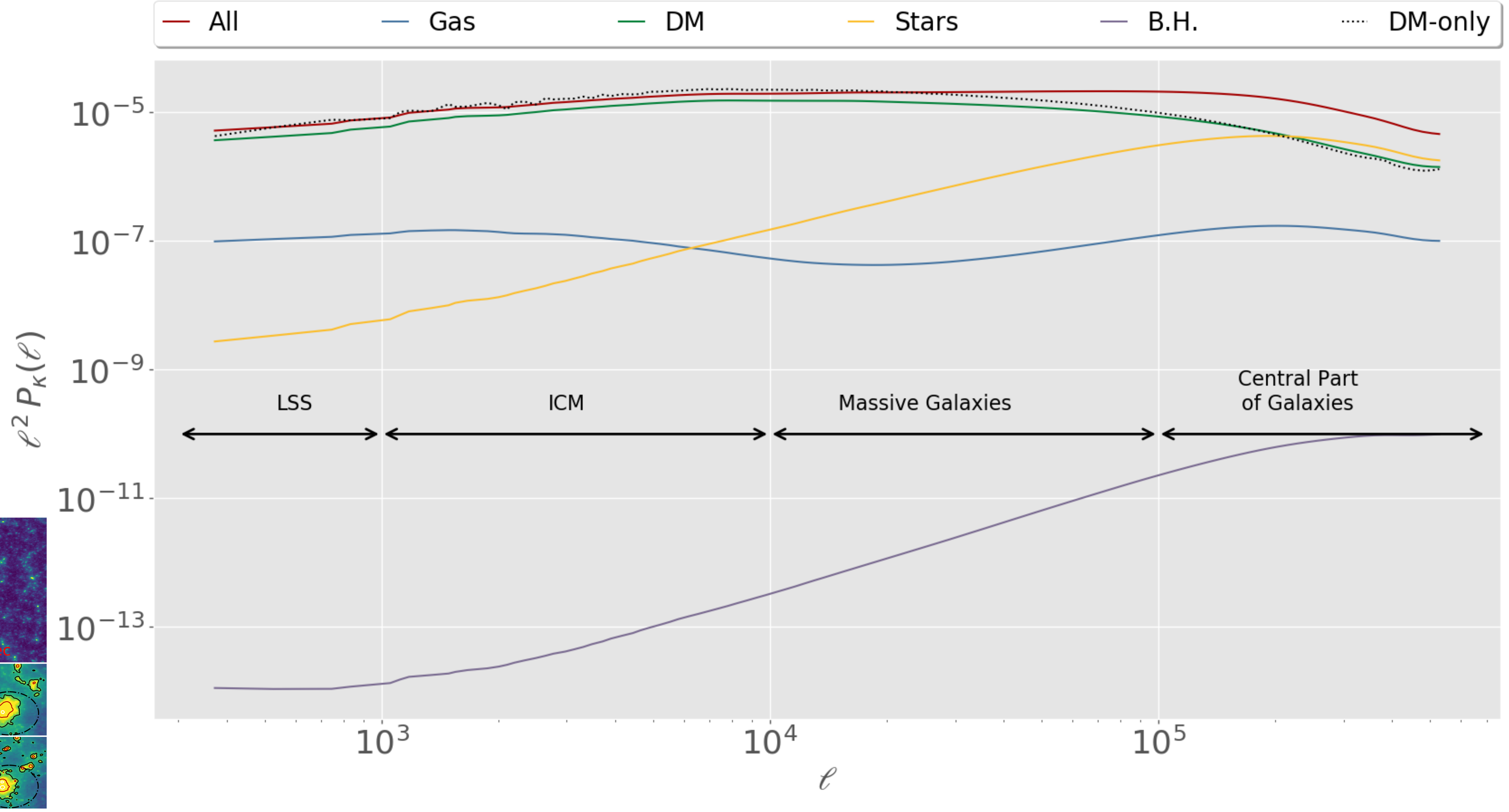


Convergence Power Spectrum

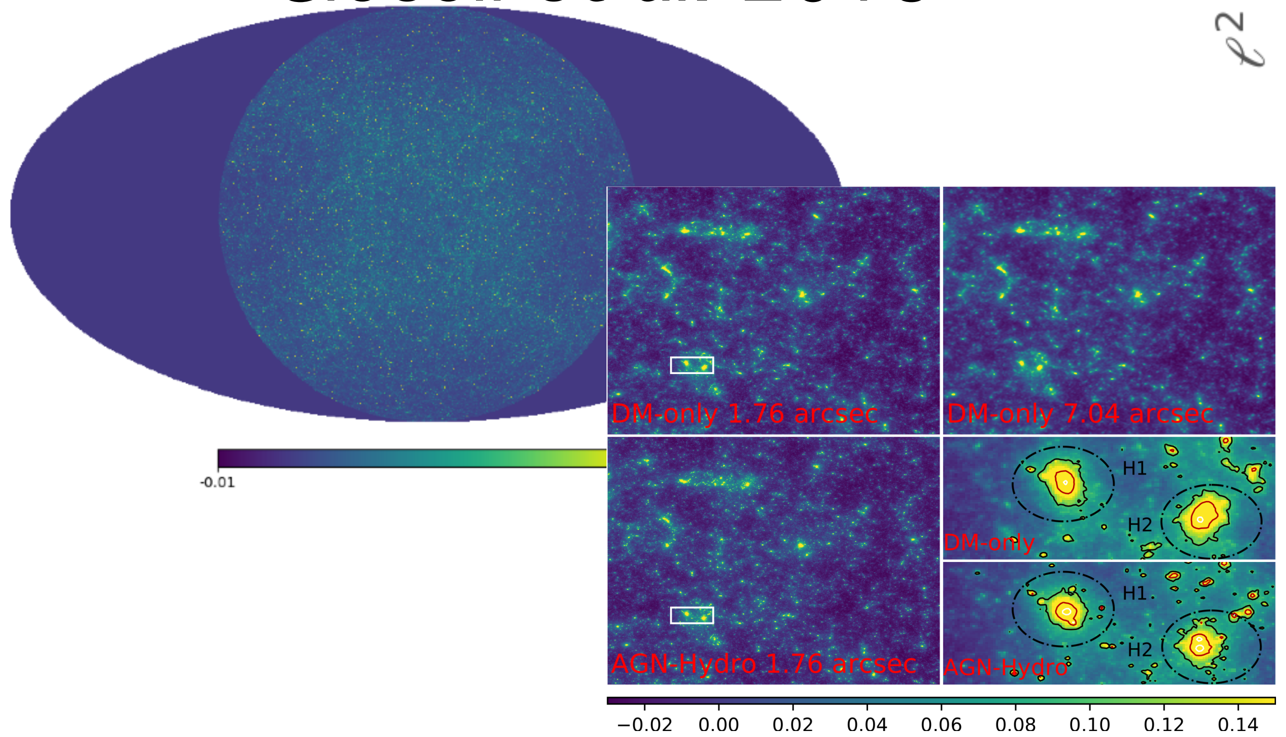
MAGNETICUM

cosmological full sph-hydro simulation





MapSim: HEALPix or FlatSky
Giocoli et al. 2015



performed high resolution lensing light-cones of the various boxes, comparison between DM-only and baryon runs allow to quantify the effect of the different baryonic systems on lensing quantities

Castro, Quartin, Giocoli, Borgani and Dolag 2018

Convergence Power Spectrum

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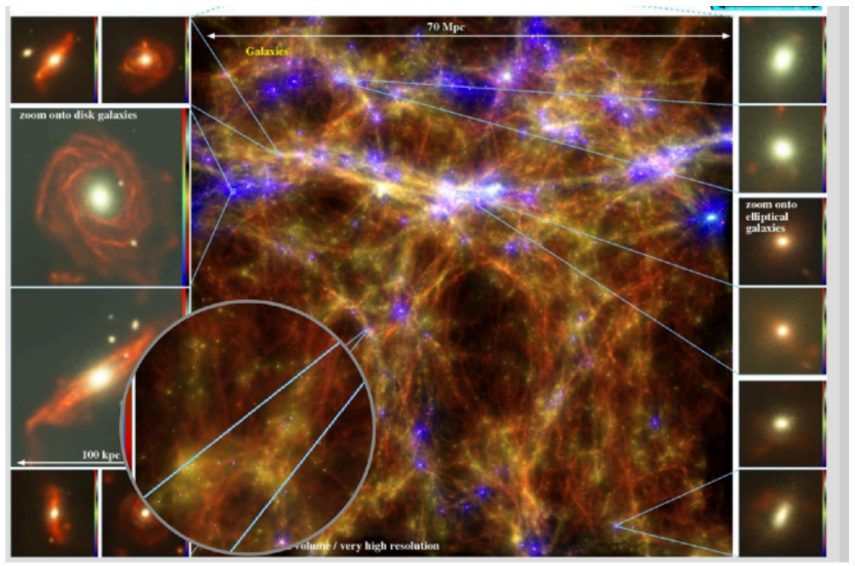

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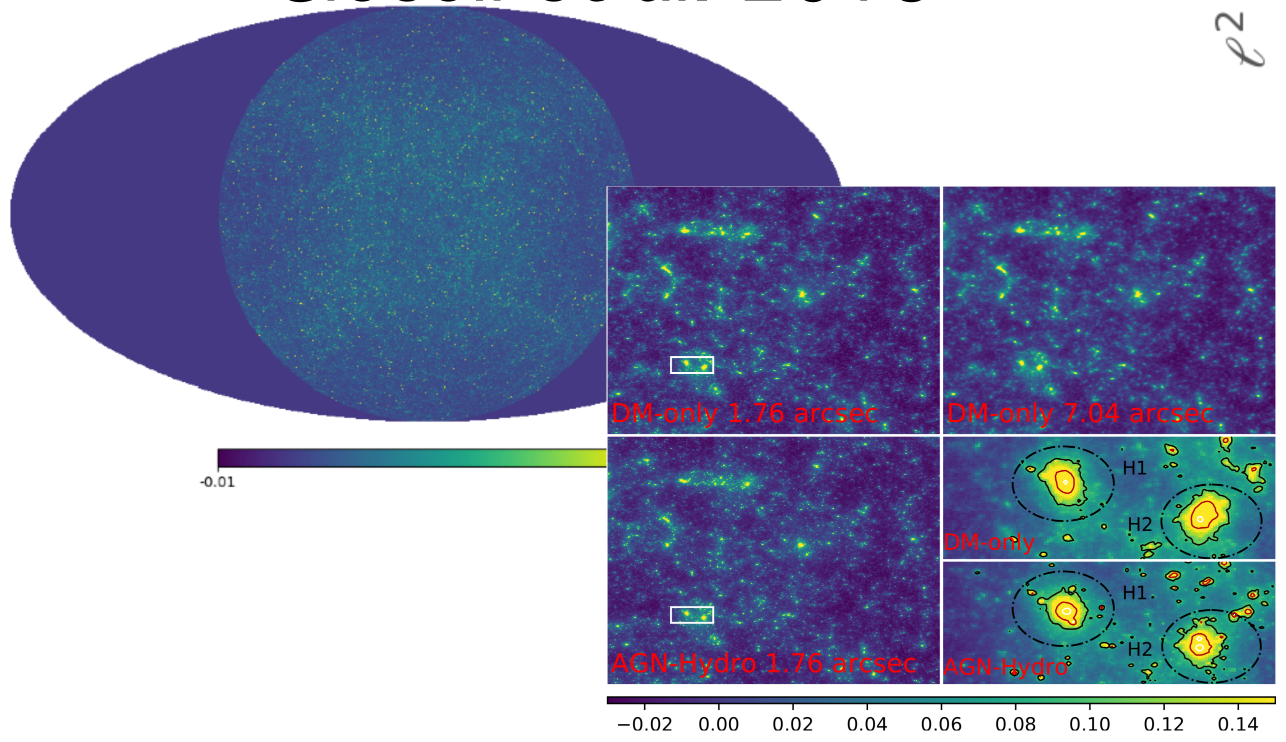
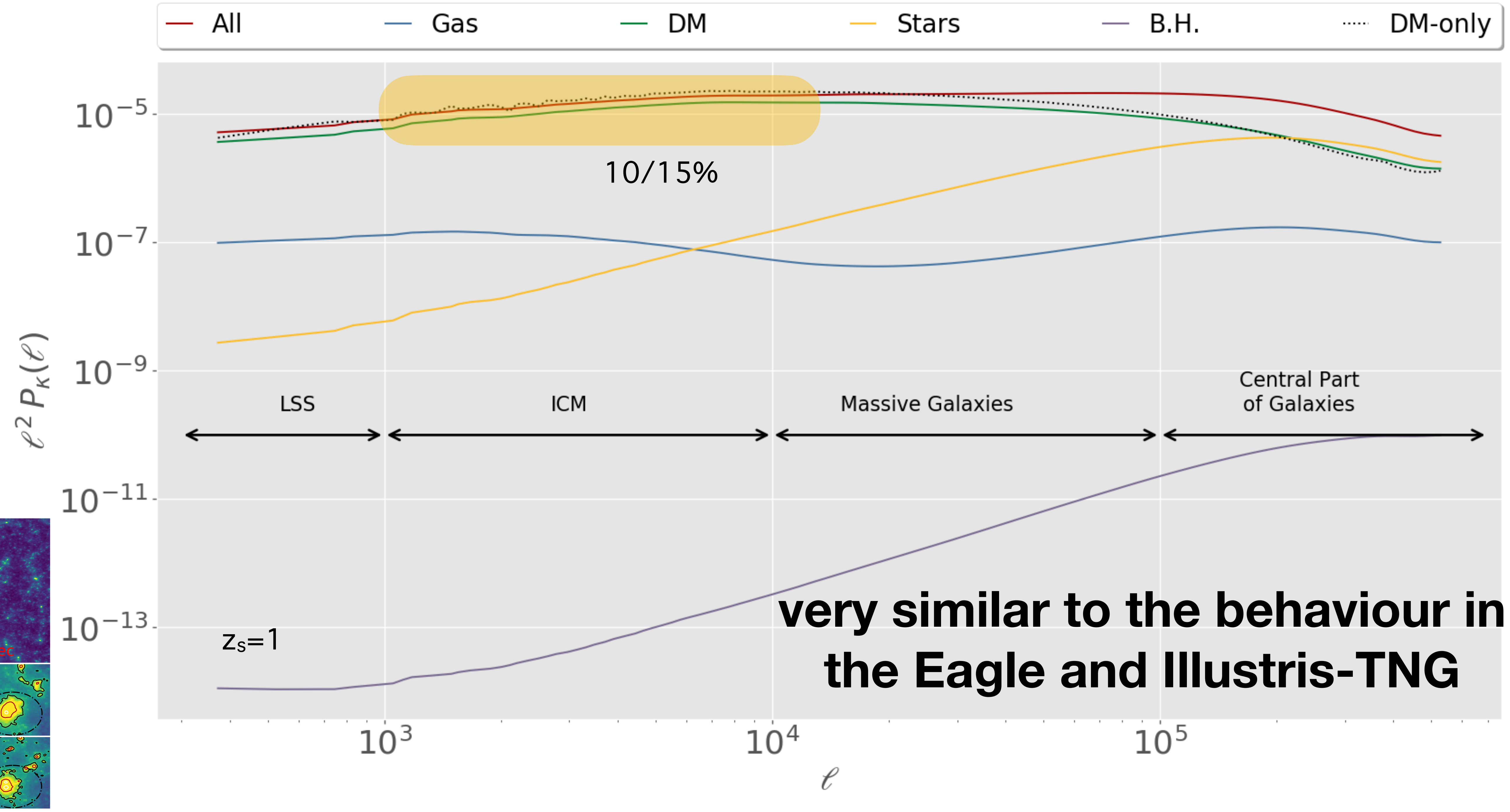
Giocoli et al. 2015





very similar to the behaviour in the Eagle and Illustris-TNG

performed high resolution lensing light-cones of the various boxes, <u>comparison</u> between DM-only and baryon runs allow to quantify the effect of the different baryonic systems on lensing quantities

Castro, Quartin, Giocoli, Borgani and Dolag 2018

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Modified Gravity Models

Hu and Sawicki 2007

DUSTGRAIN-*pathfinder* runs: 750 Mpc/h and 768^3 DM part.

		f_{R0}	neutrino mass eV
ΛCDM	GR	–	0
fR4	$f(R)$	-1×10^{-4}	0
fR5	$f(R)$	-1×10^{-5}	0
fR6	$f(R)$	-1×10^{-6}	0
fR4-0.3eV	$f(R)$	-1×10^{-4}	0.3
fR5-0.15eV	$f(R)$	-1×10^{-5}	0.15
fR5-0.1eV	$f(R)$	-1×10^{-5}	0.1
fR6-0.1eV	$f(R)$	-1×10^{-6}	0.1
fR6-0.06eV	$f(R)$	-1×10^{-6}	0.06

Giocoli, Baldi and Moscardini 2018
Peel, Pettorino, Giocoli, Starck, Baldi 2018
Merten, Giocoli, Baldi et al. 2019
Girelli et al. (incl. Giocoli) 2020

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Light-Cone Construction

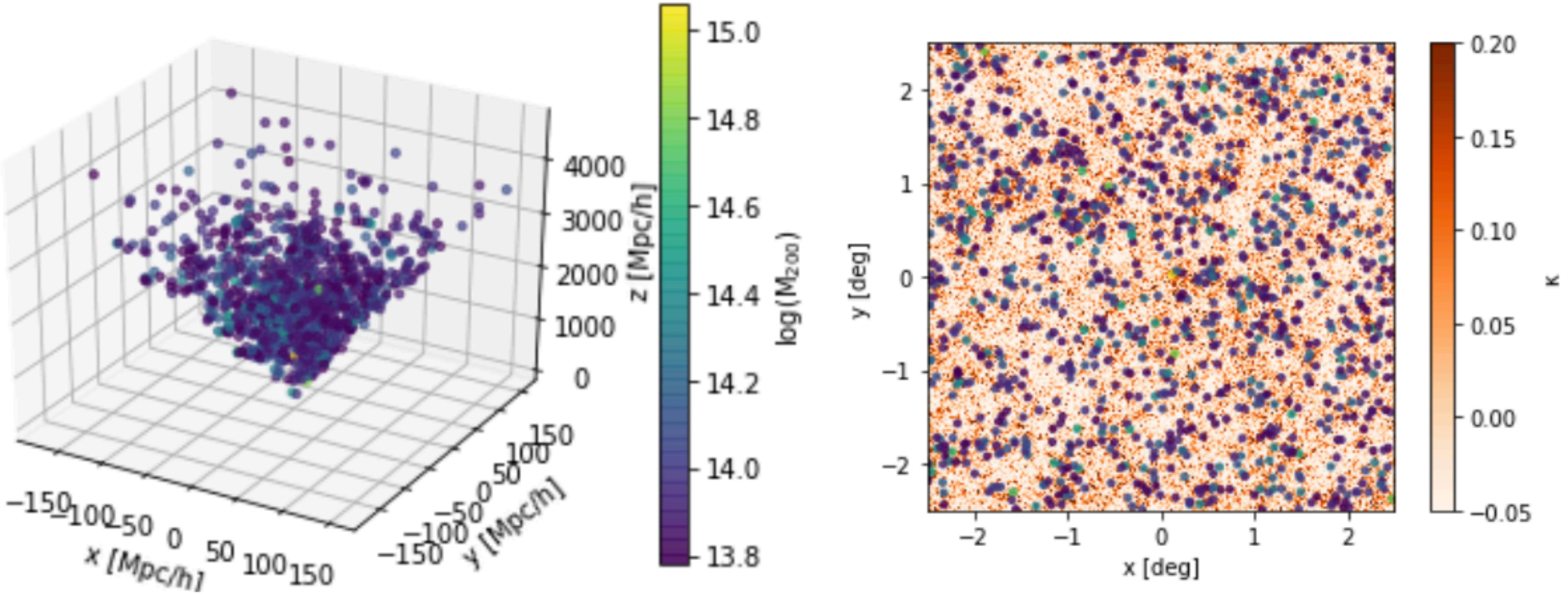
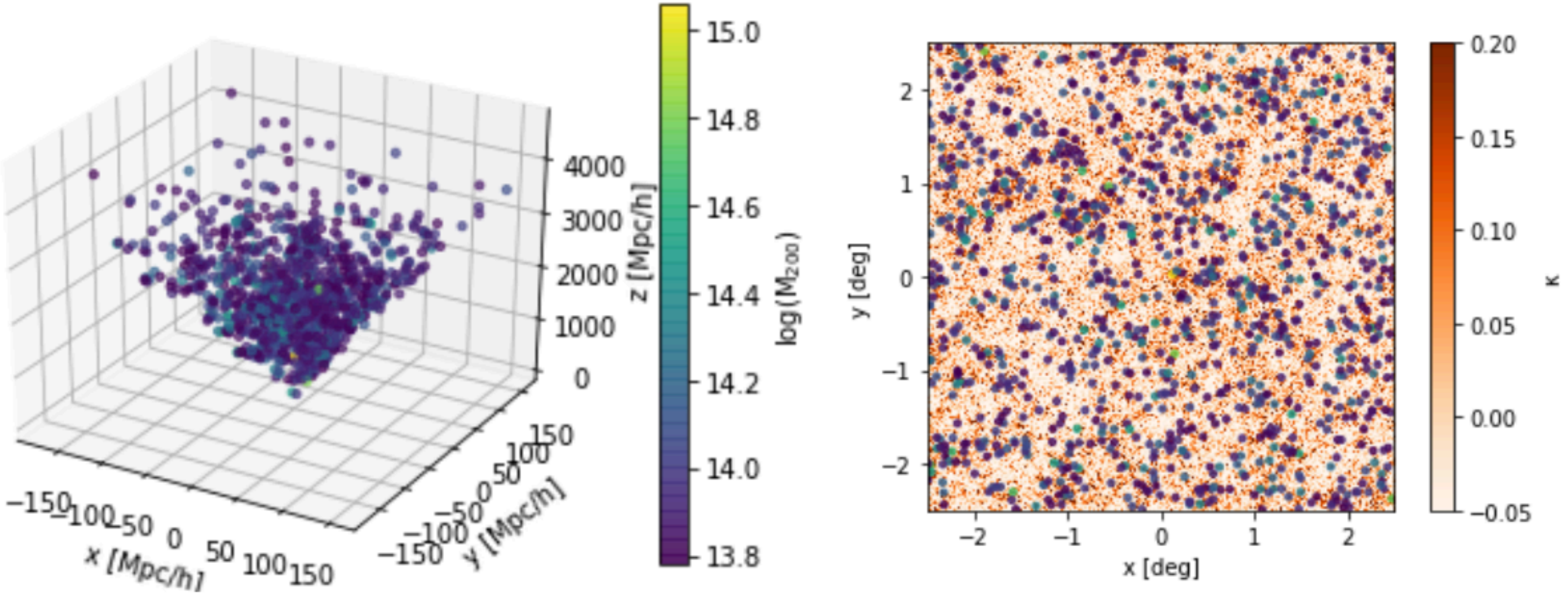


Figure 3. Schematic representation of the past-light-cone using our MapSim routine. Left panel shows the three-dimensional distribution of haloes within the light-cone with 5×5 sq. deg. aperture up to redshift z = 4. We display all haloes with mass larger than $M_{200} \geq 6 \times 10^{13} M_{\odot}/h$ colour coded according to their mass. Right panel shows the convergence map for z_s = 4 – which represents the base of our past-light-pyramid – on which we display also the projected distribution of the haloes present with the field of view.

for each simulation we have generated 256 different light-cone randomisations with 5x5 deg2 up to z=4, with resolution of ~9 arcsec

Light-Cone Construction

baryons are not invited!



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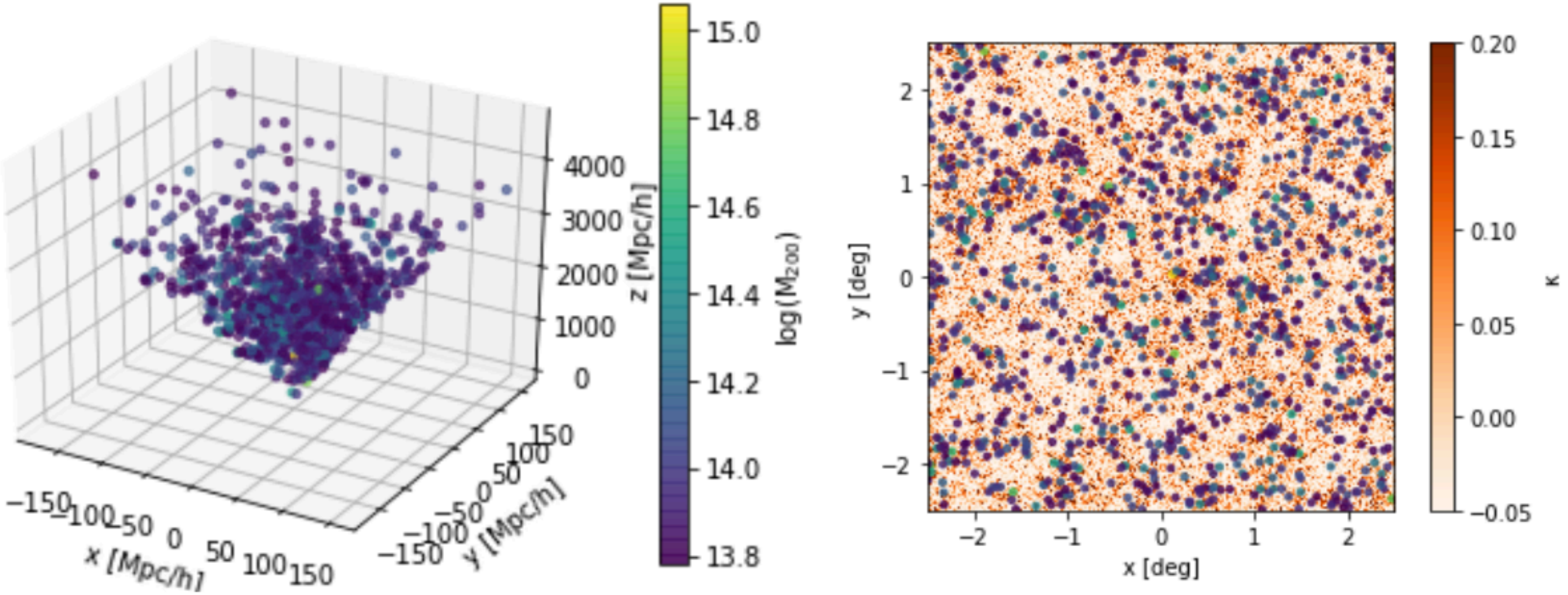

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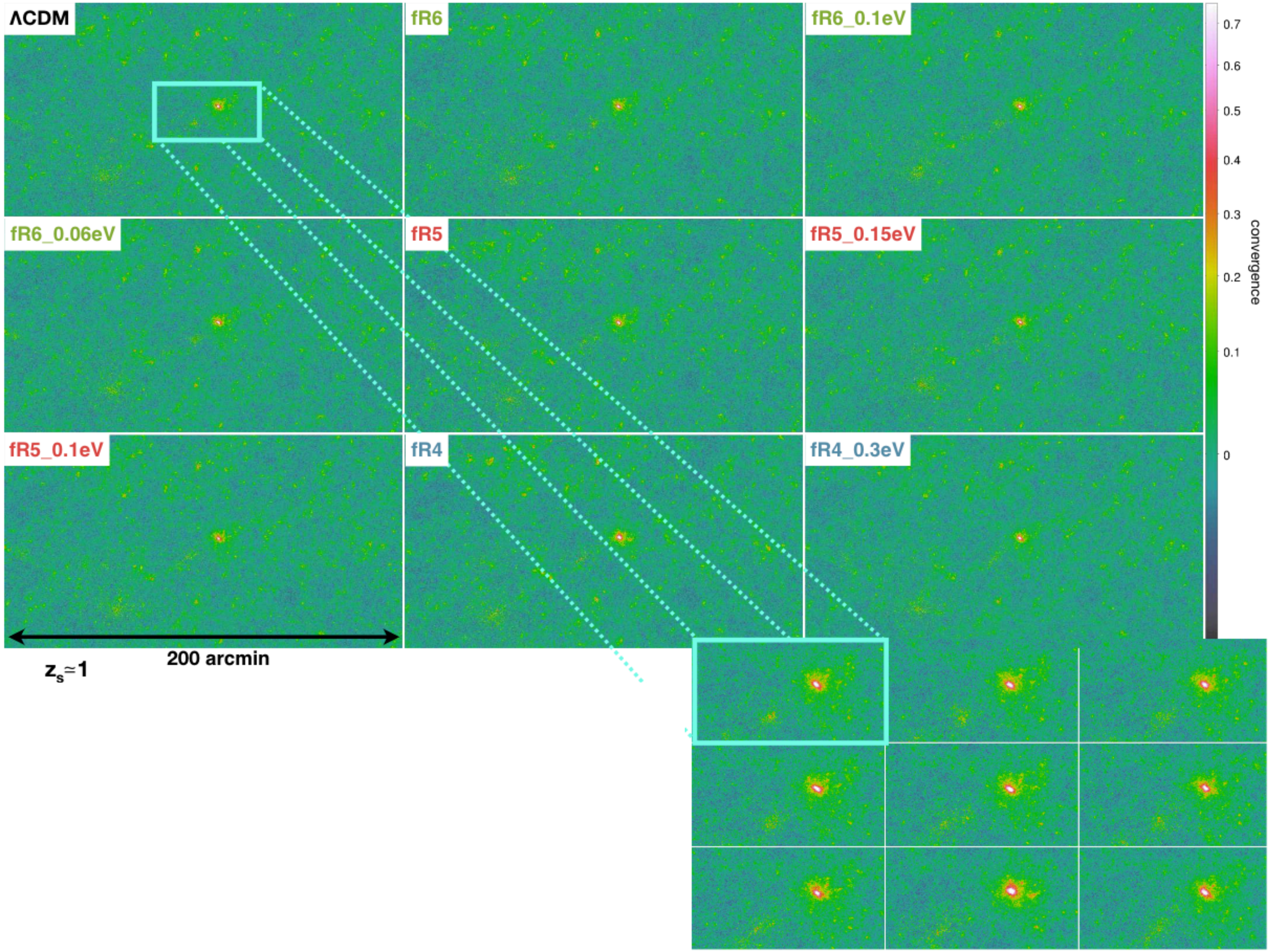
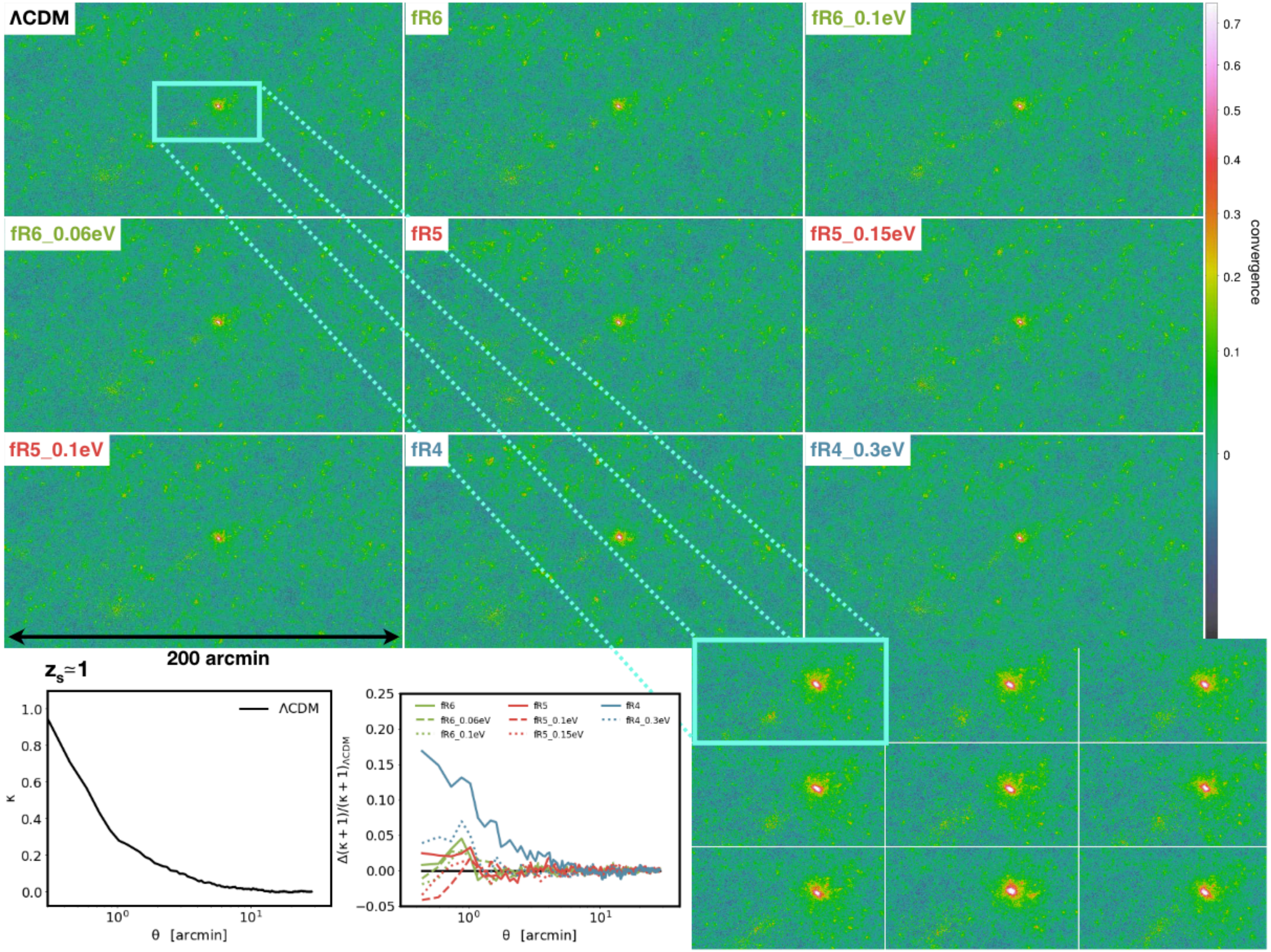


Giocoli, Baldi and Moscardini 2018

Light-Cone Construction



Giocoli, Baldi and Moscardini 2018

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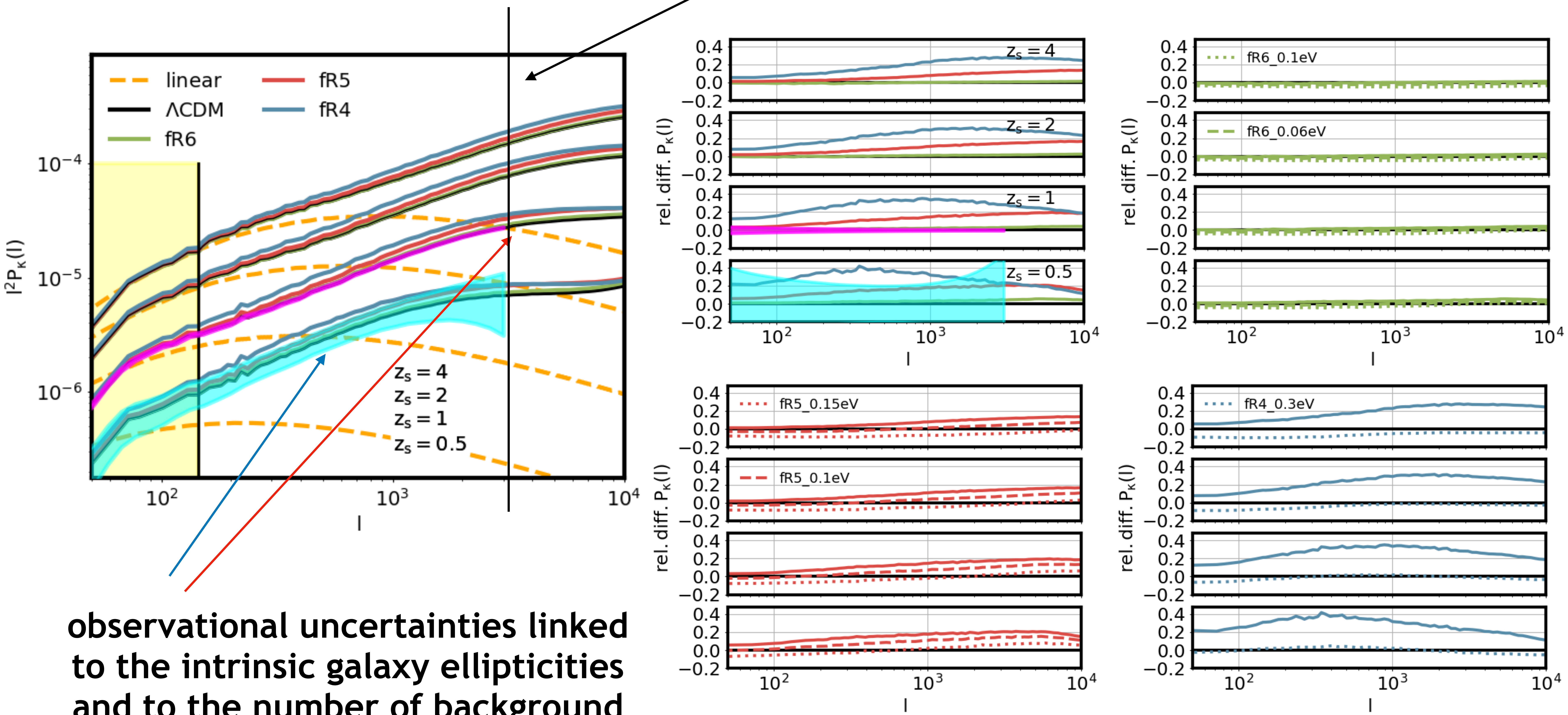
Cosmic Shear Tomography

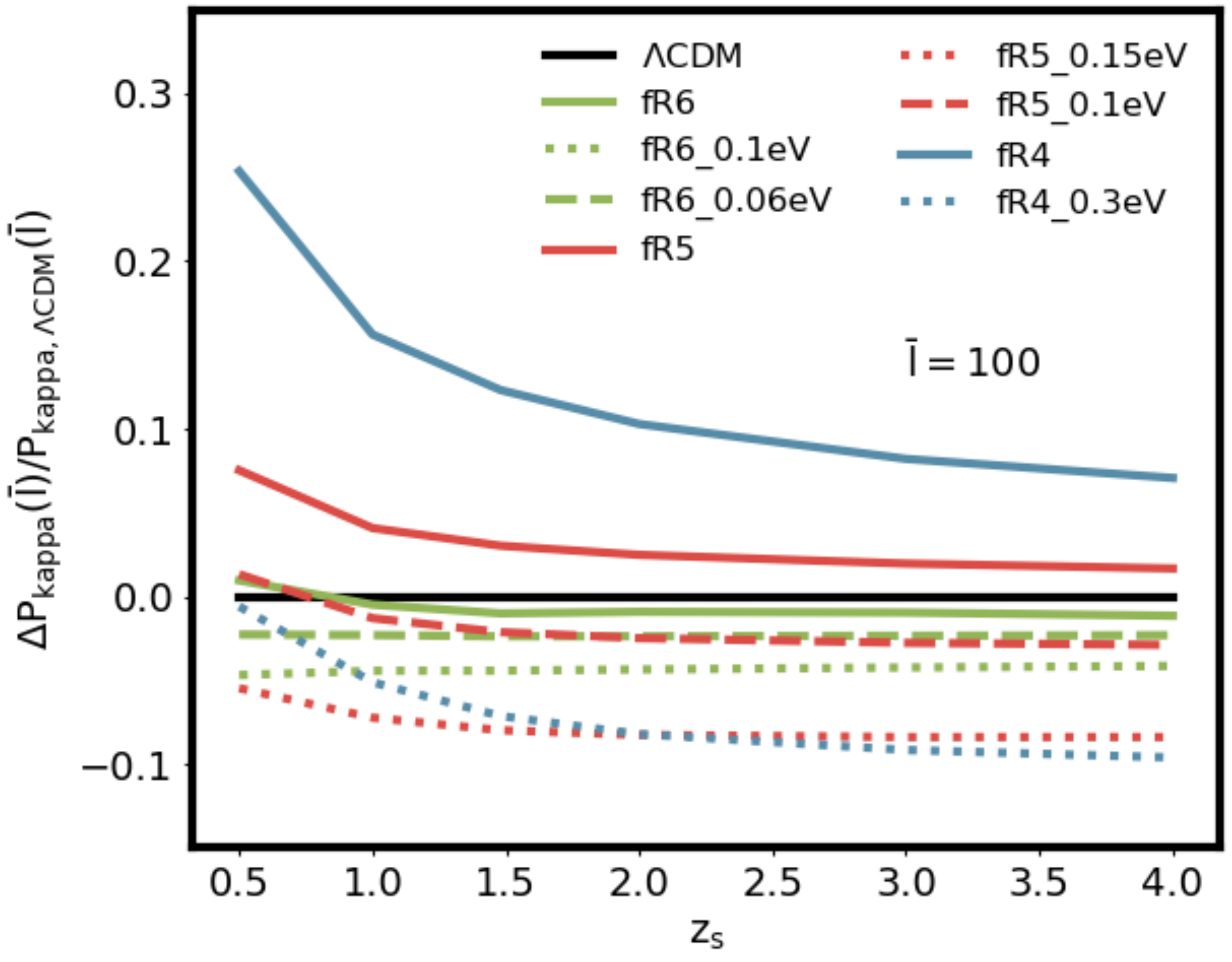
smallest scale expected to be probed
by future wide field surveys (Euclid, LSST)



observational uncertainties linked
to the intrinsic galaxy ellipticities
and to the number of background
galaxies, 18 and 32 per square arcmin

Giocoli, Baldi and Moscardini 2018

Cosmic Shear Tomography



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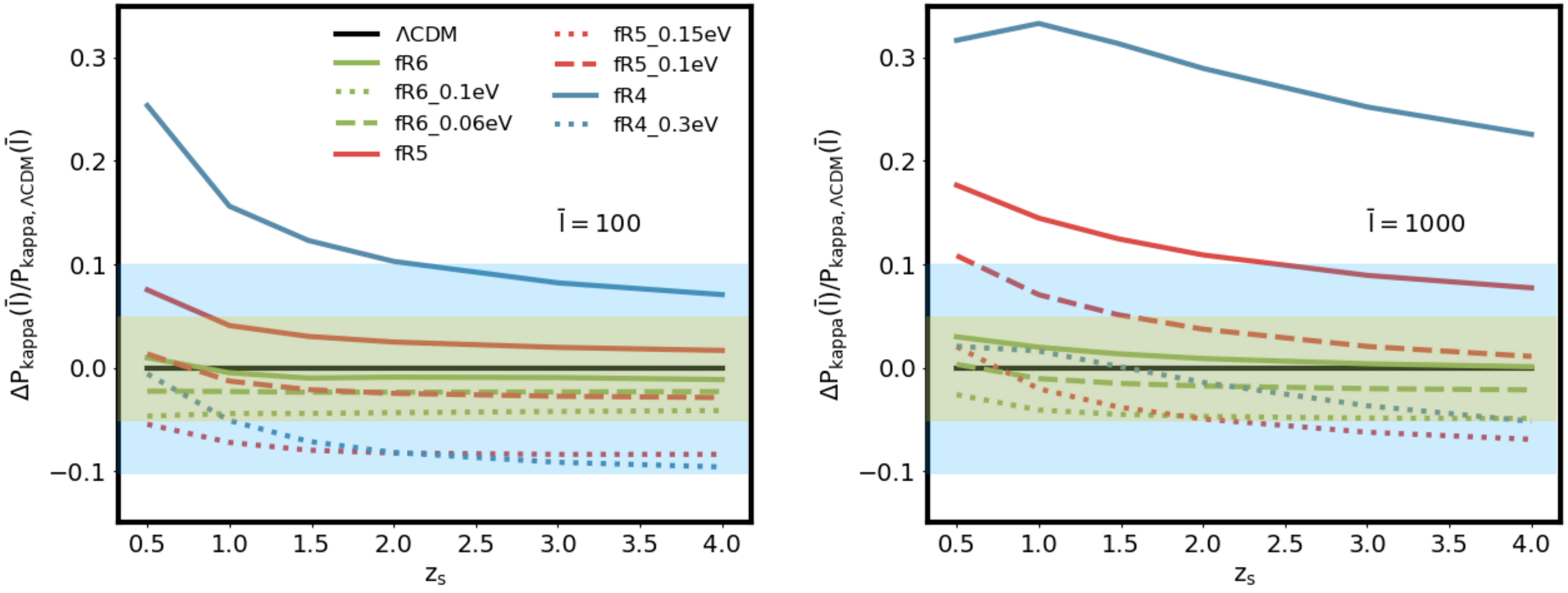
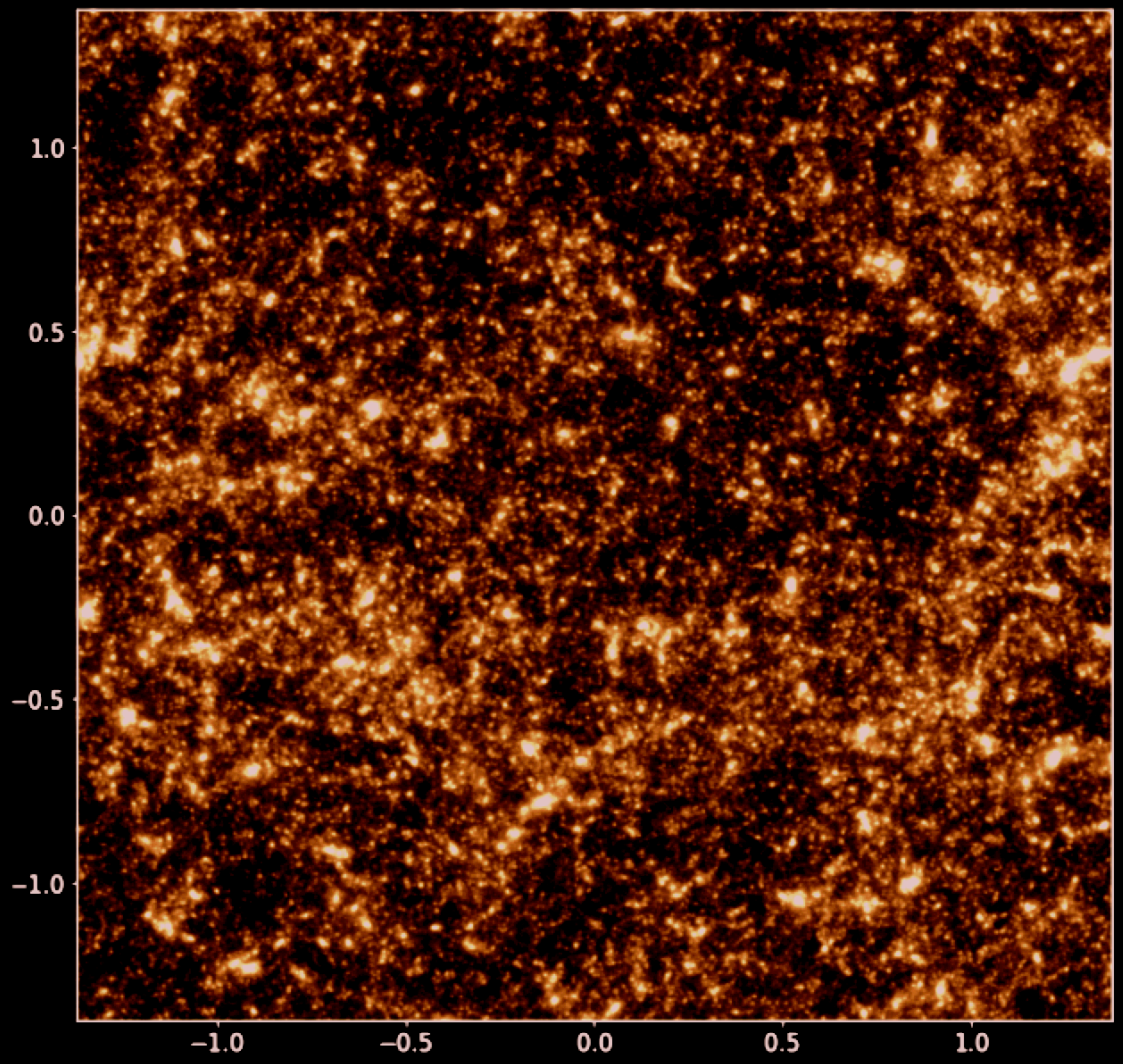
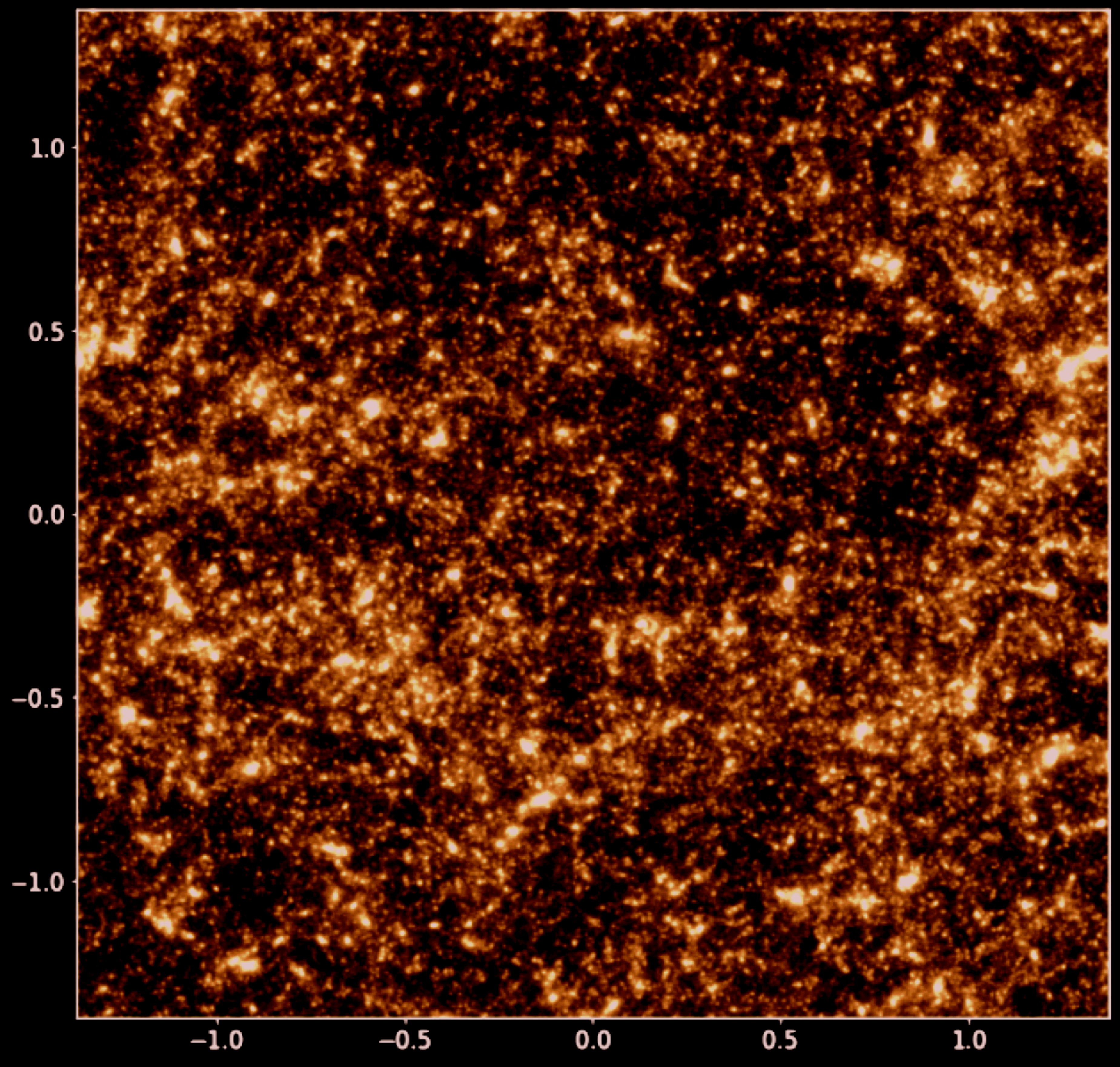
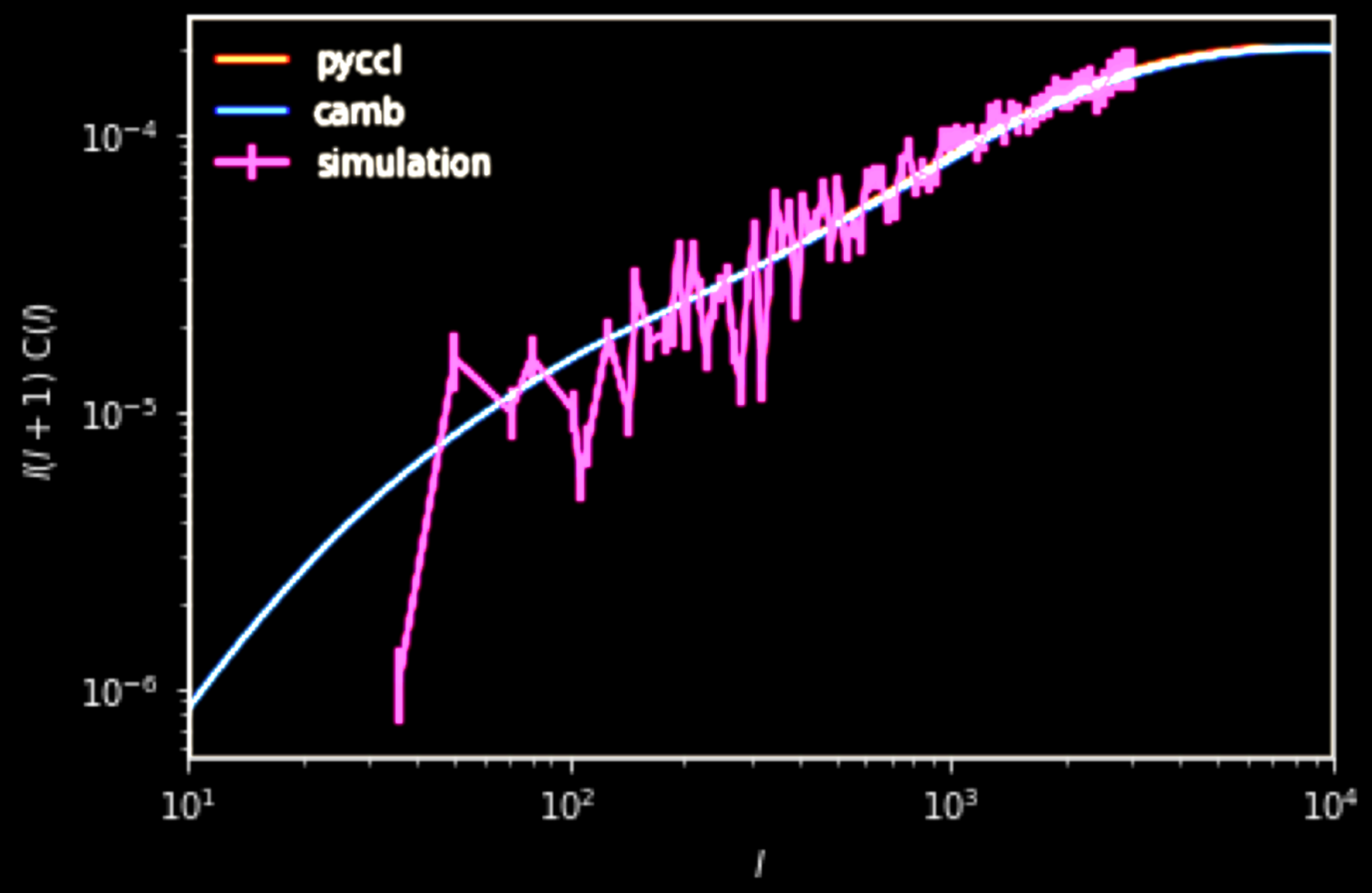


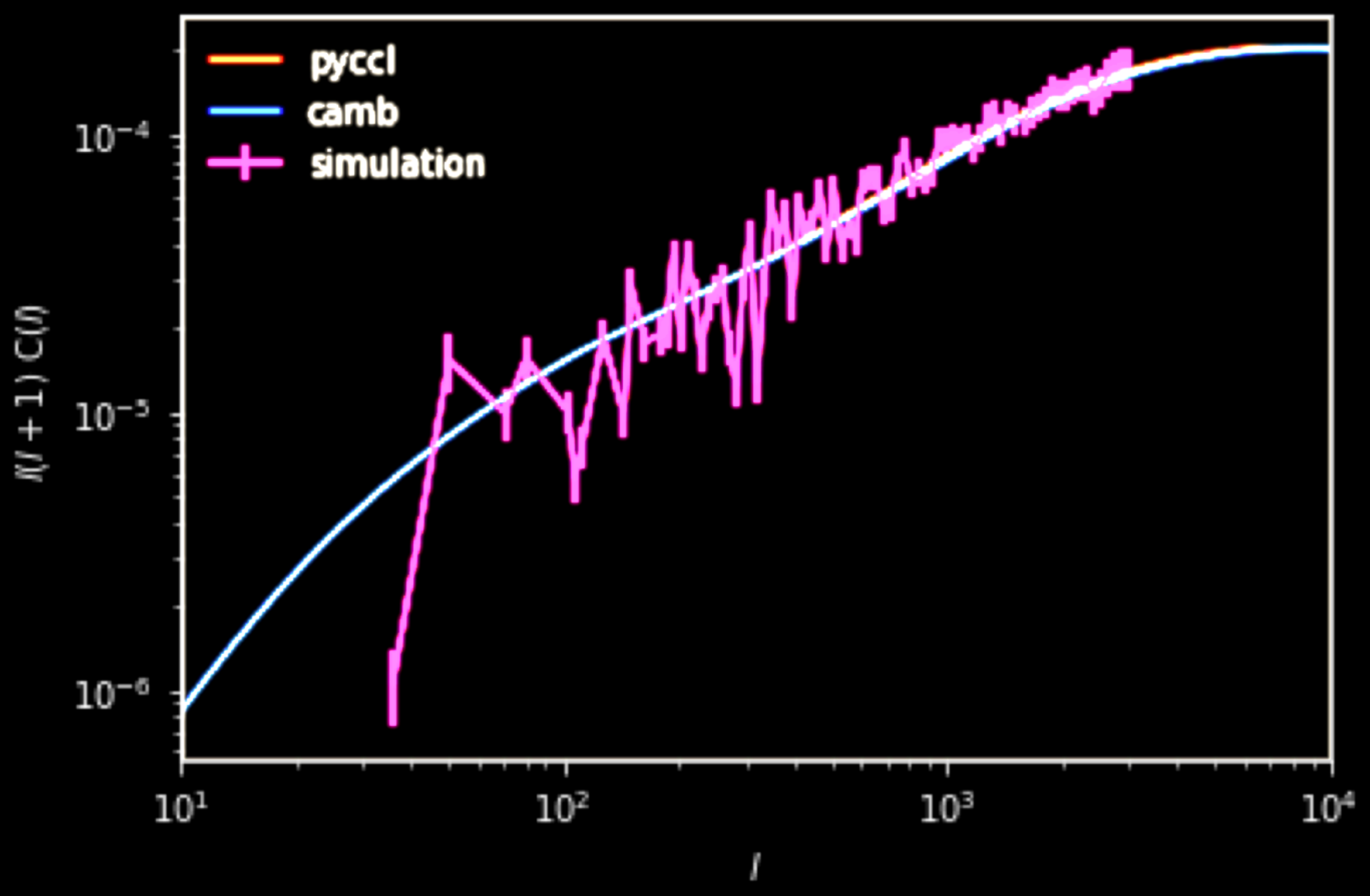
Looking at the relative contribution!


1.0
0.5
0.0
−0.5
−1.0
−1.0
−0.5
0.0
0.5
1.0

2pt-Statistic







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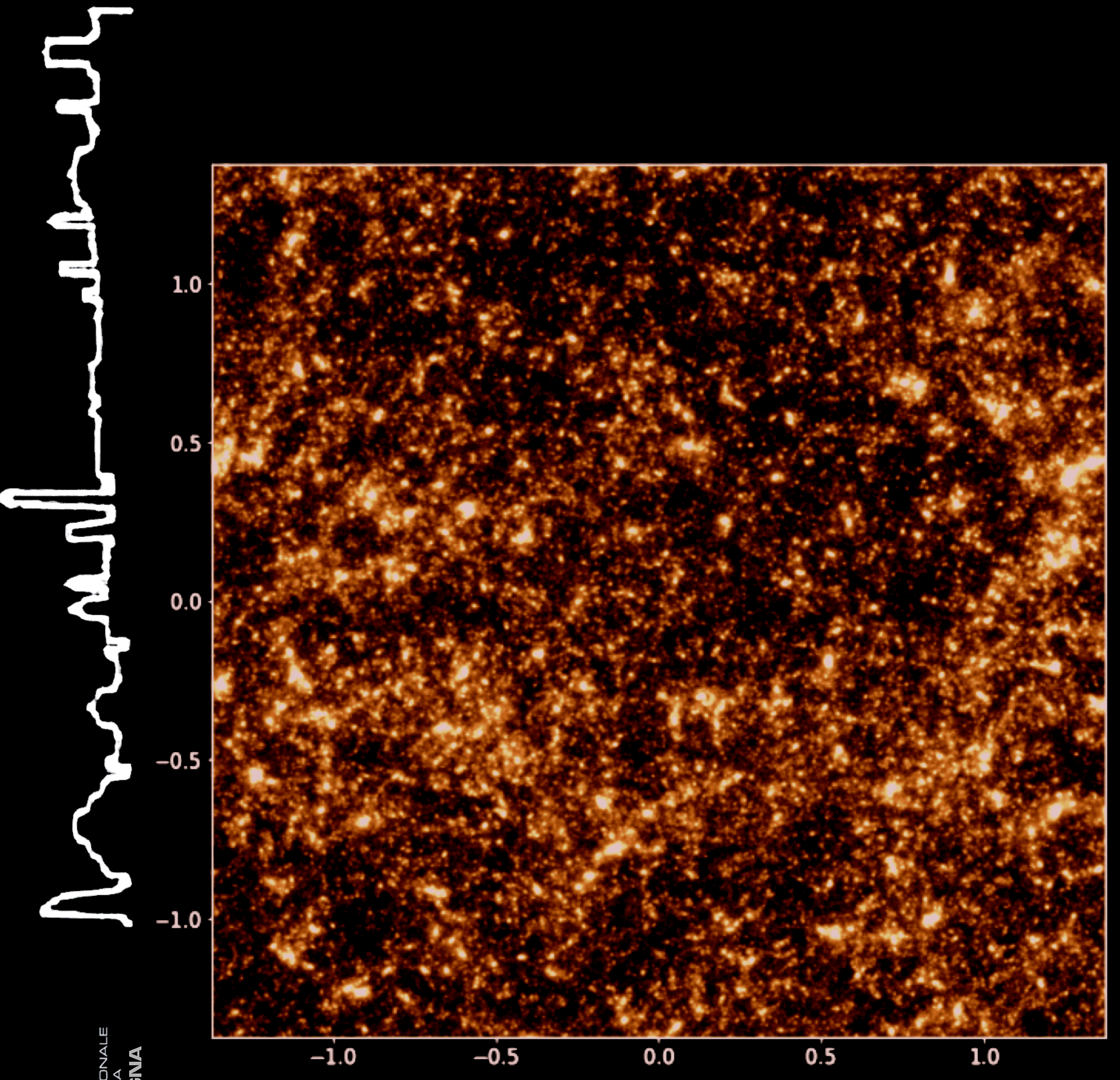
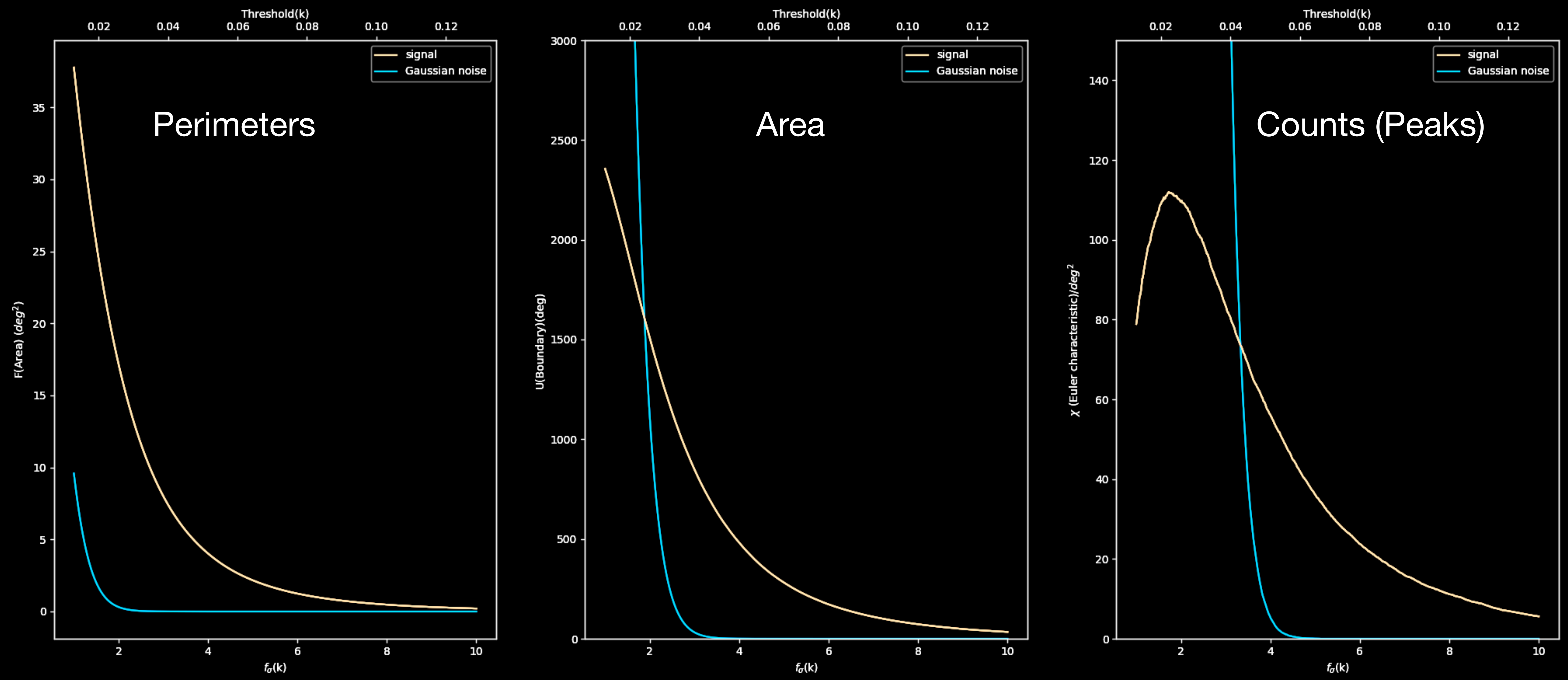




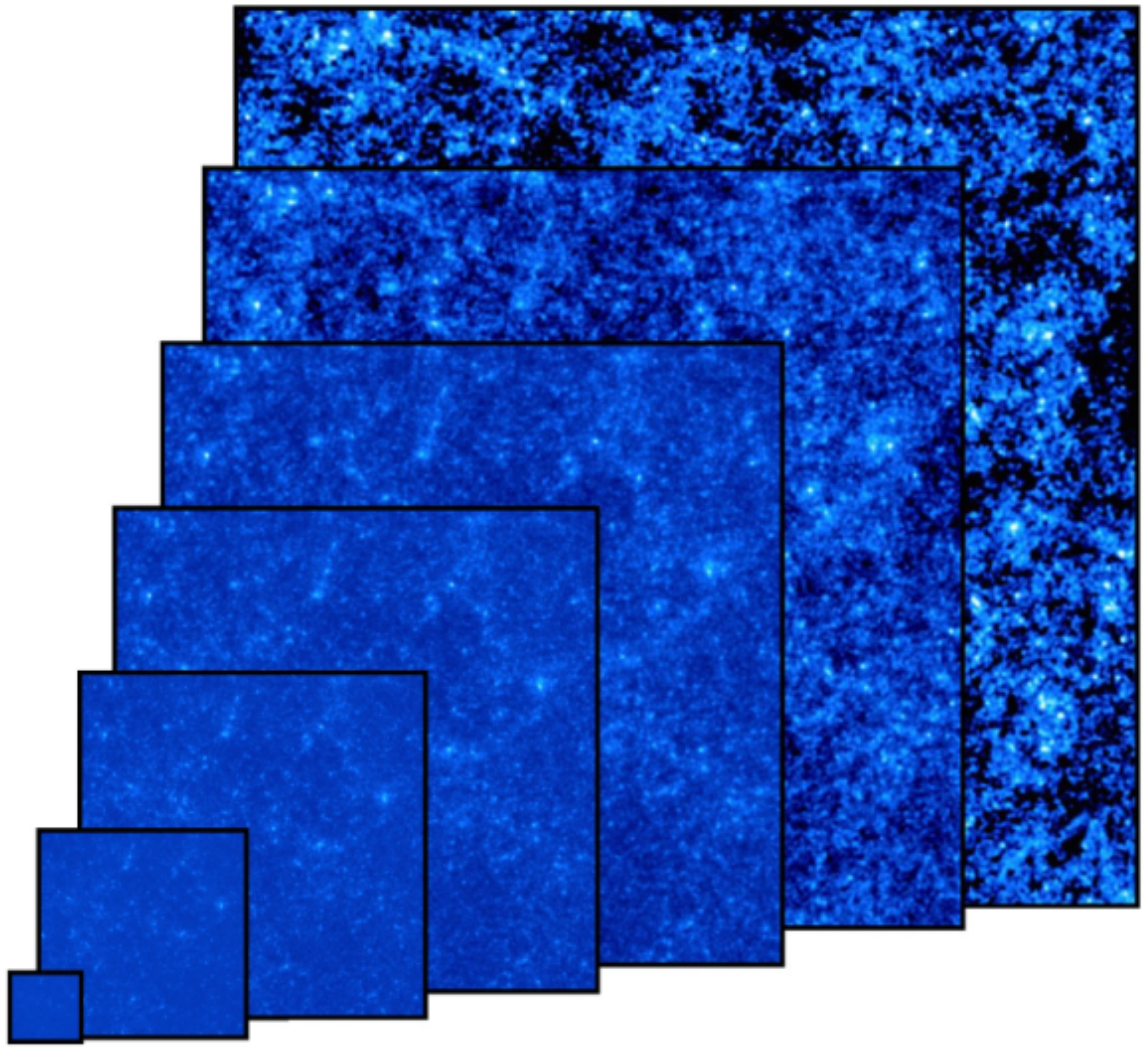
High-Order-Statistics

Teresa De Candia Master Thesis

Howl Project

joint project: Mass Mapping and High Order Statistic WP (Simulations and Weak Lensing)

Baldi, Cardone, Giocoli, Martinet, Pires, Tereno
and collaborators



kick-off telecon

Nicolas Martinet, Vincenzo F. Cardone, Martina Vicinanza, Ismael Tereno, Carlo Giocoli, Carolina Parroni, Sandrine Pires, Austin Peel, Antonio da Silva, Arun Kannawadi, Melita Carbone, Julian Merten, Matthew Price,

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HOwL'S – Aims and Methods

Why HOWL'S

- Going higher than 2nd order to break parameters degeneracies
- Compare different methods to find the better strategy
- Check for correlations among probes and with 2nd order statistic
- Quantify the impact of systematics in self consistent way

How HOWL'S

- a three steps procedure
  - I. produce simulated shear and convergence maps
  - II. measure high order statistics quantities on common maps
  - III. compare results with and without shear tomography
- further byproducts
  - a. investigate dependence on (common) systematics
  - b. joint use of different higher order probes

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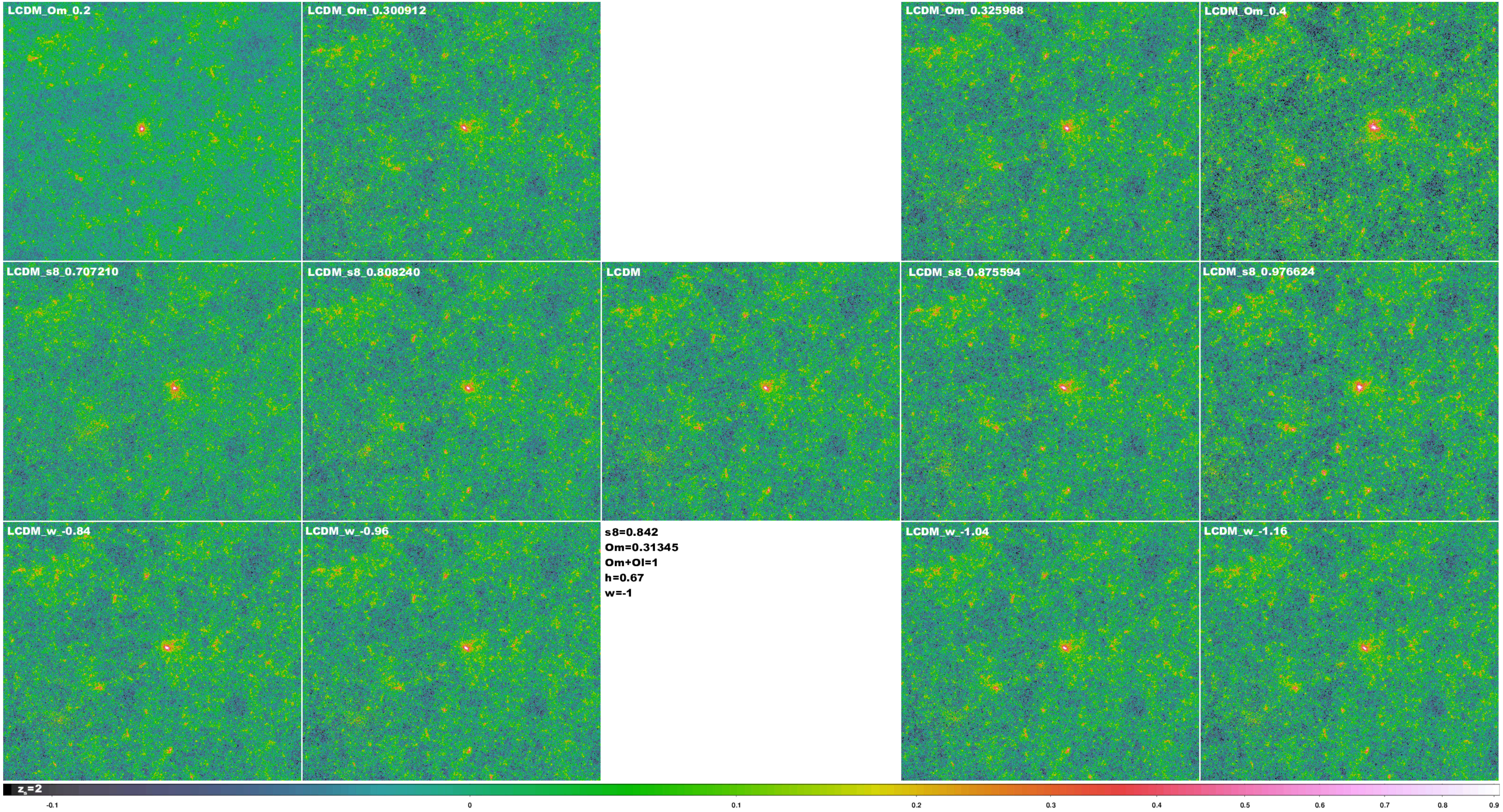

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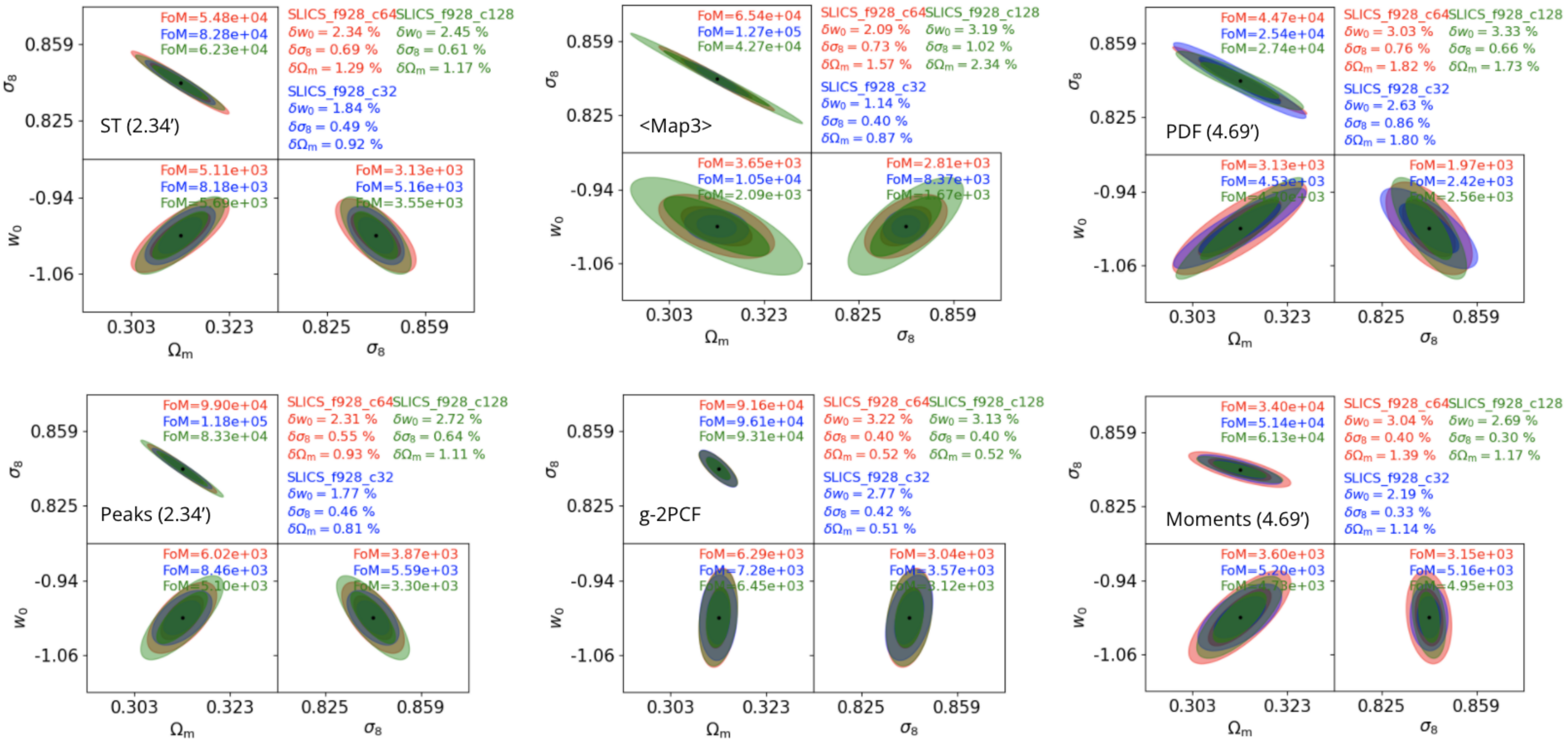
Cosmological Fisher analyses of high-order-statistics



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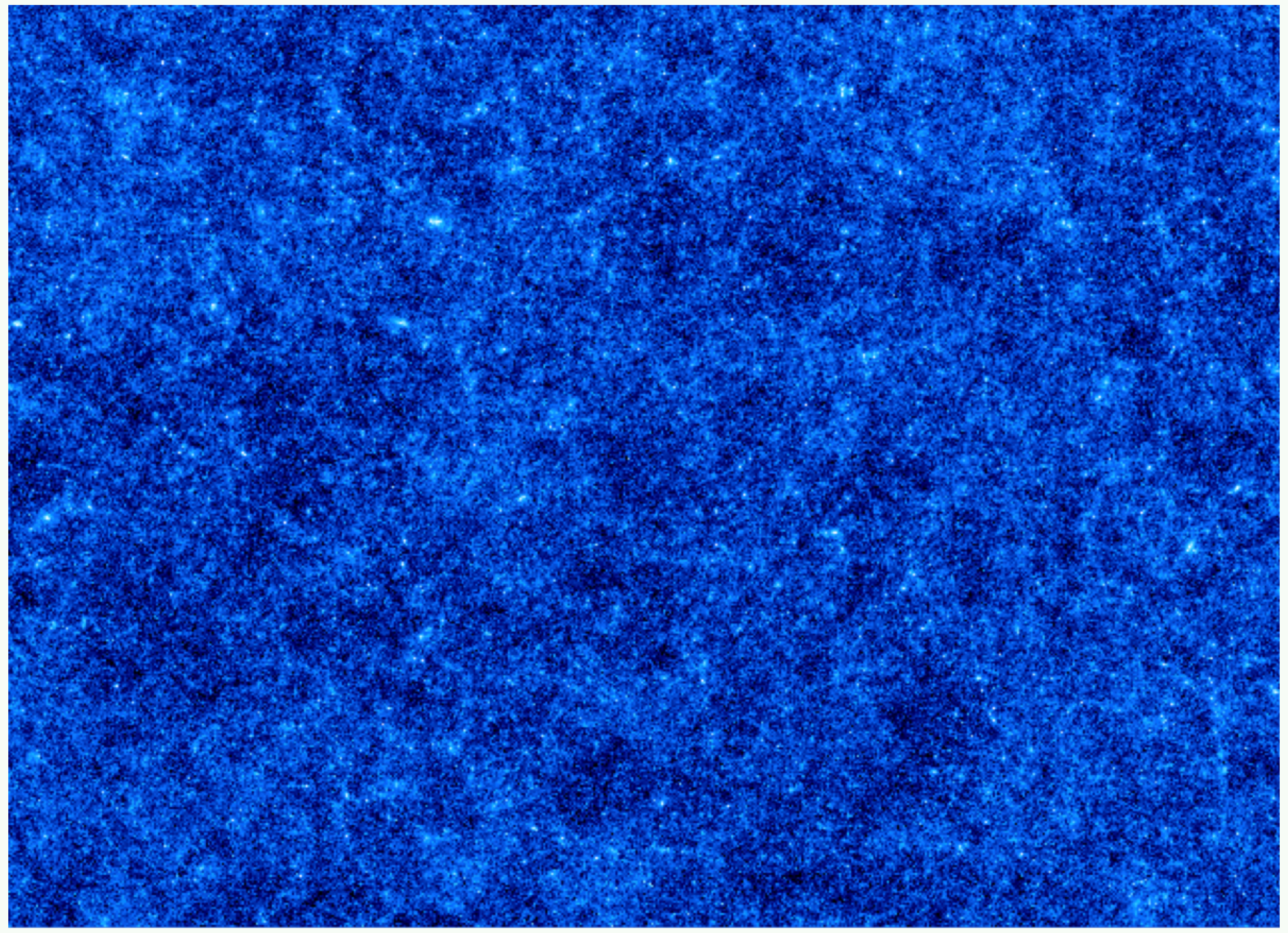
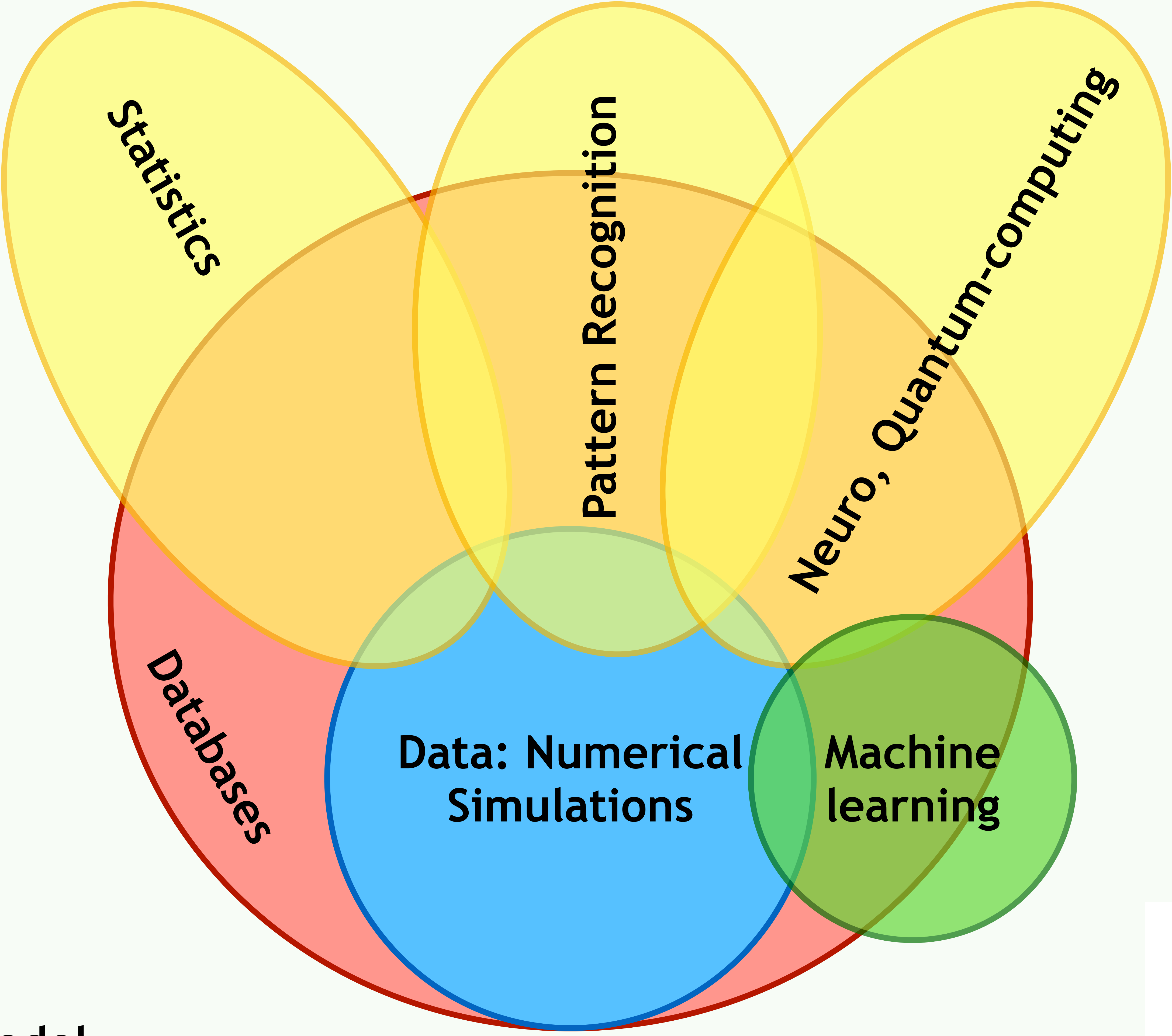
Summary

"Let There Be More Light"-Cones





- Database of Light-Cone simulations
- New statistical tool to analyse data
- Peak statists is powerful: calibrate model
- Combine cosmological probes for future wide field surveys

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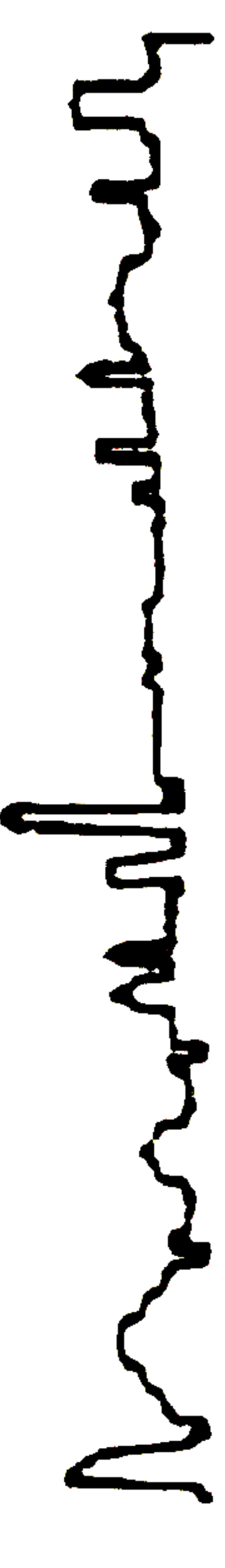

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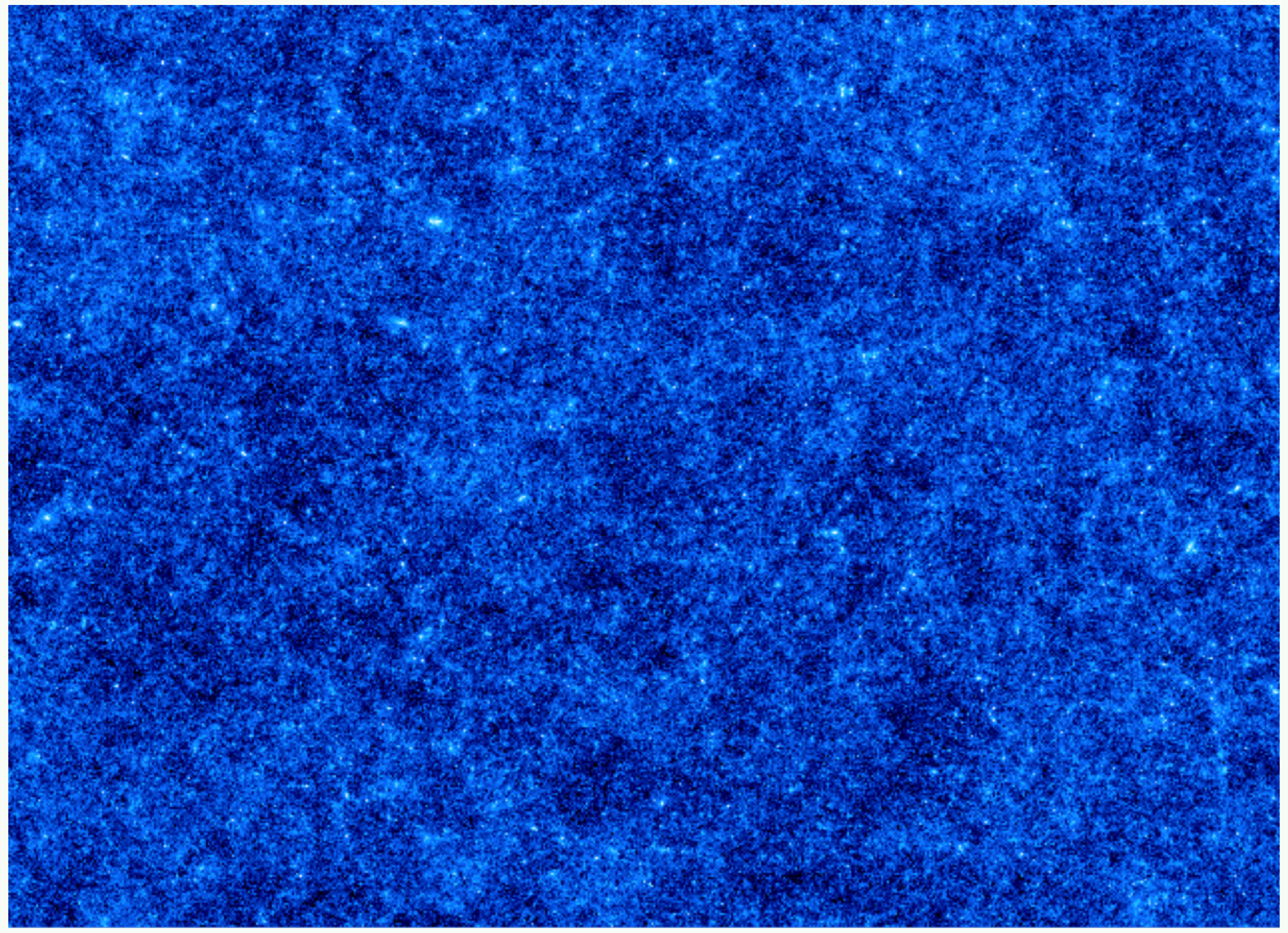

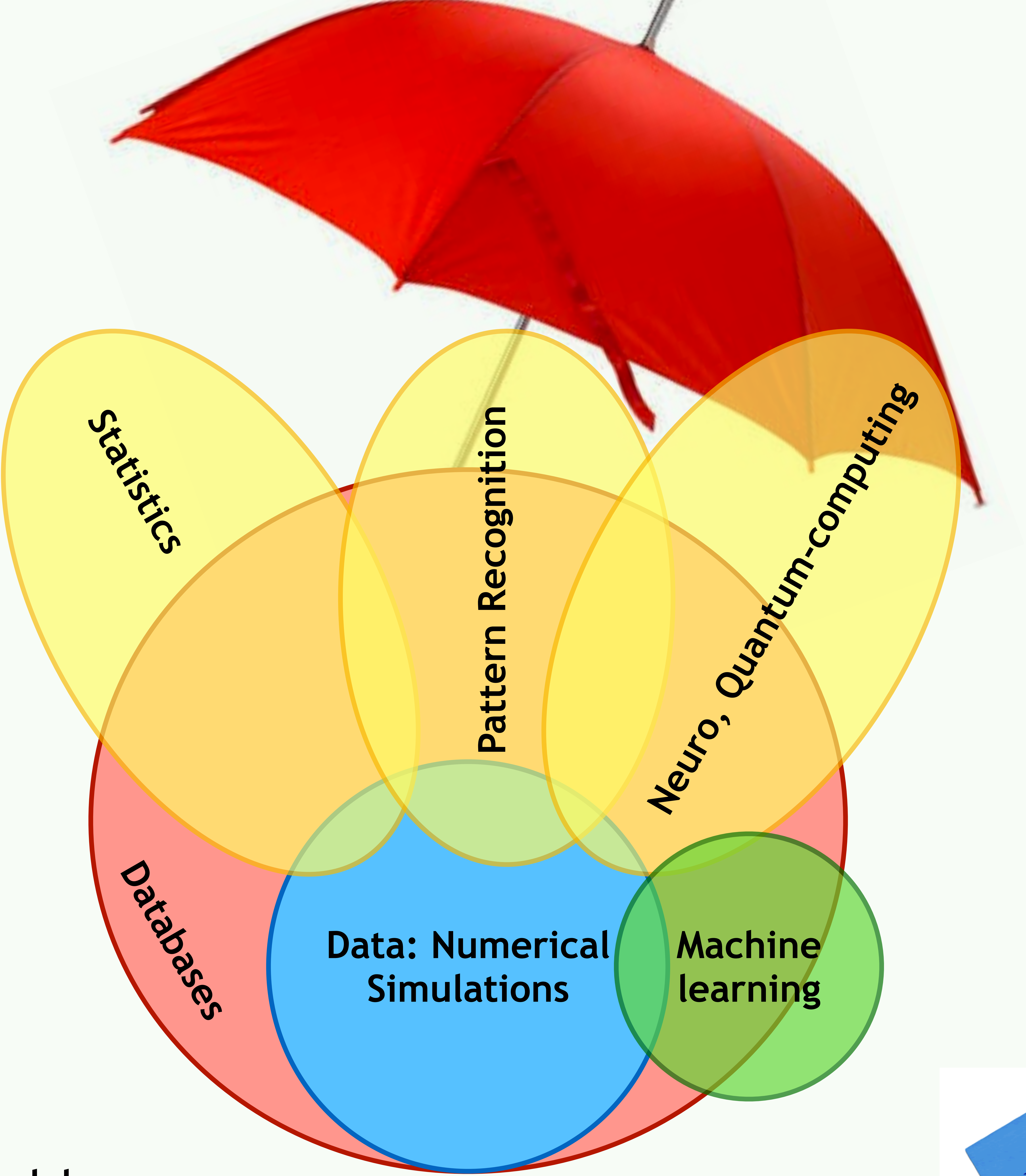

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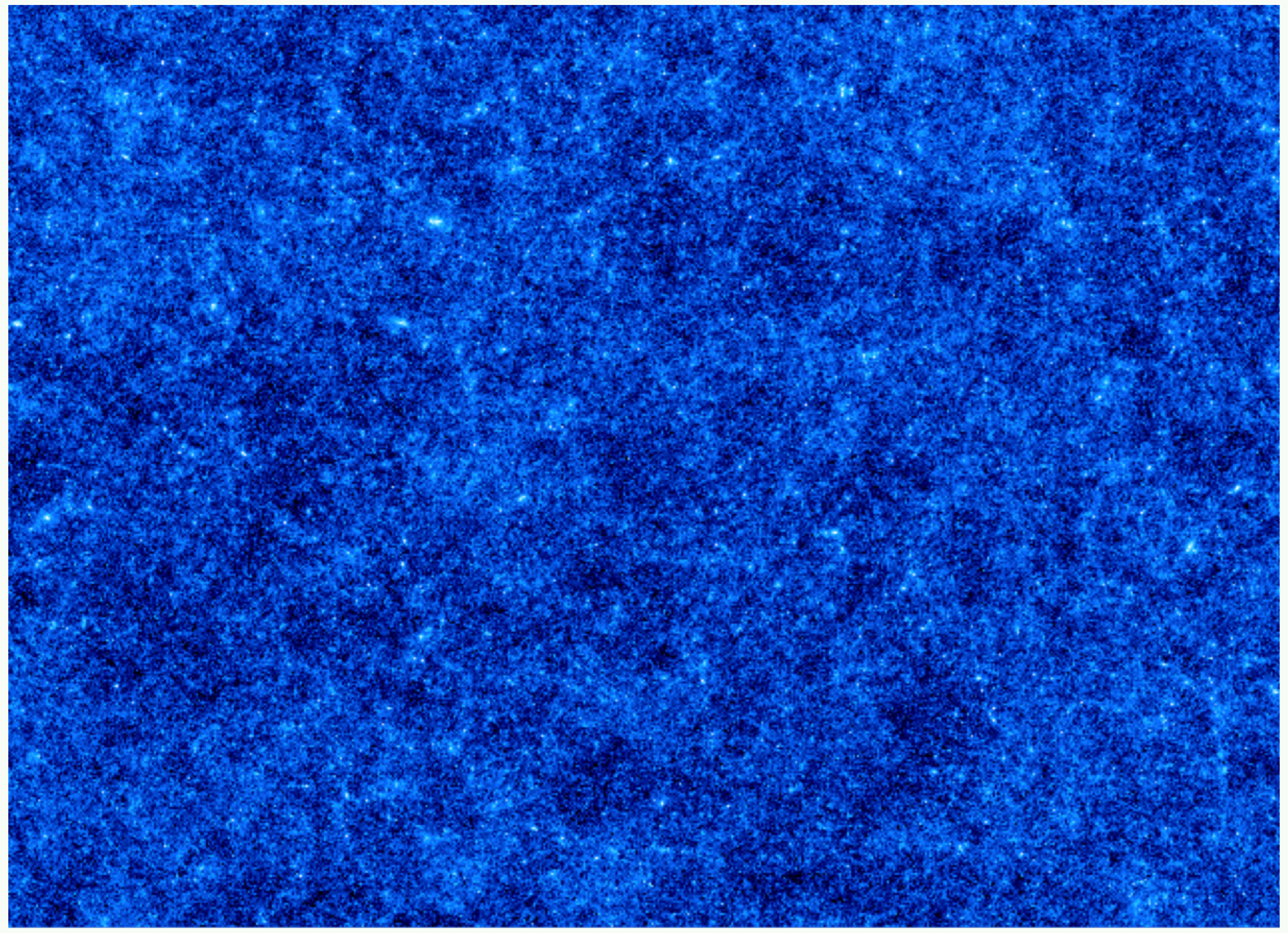

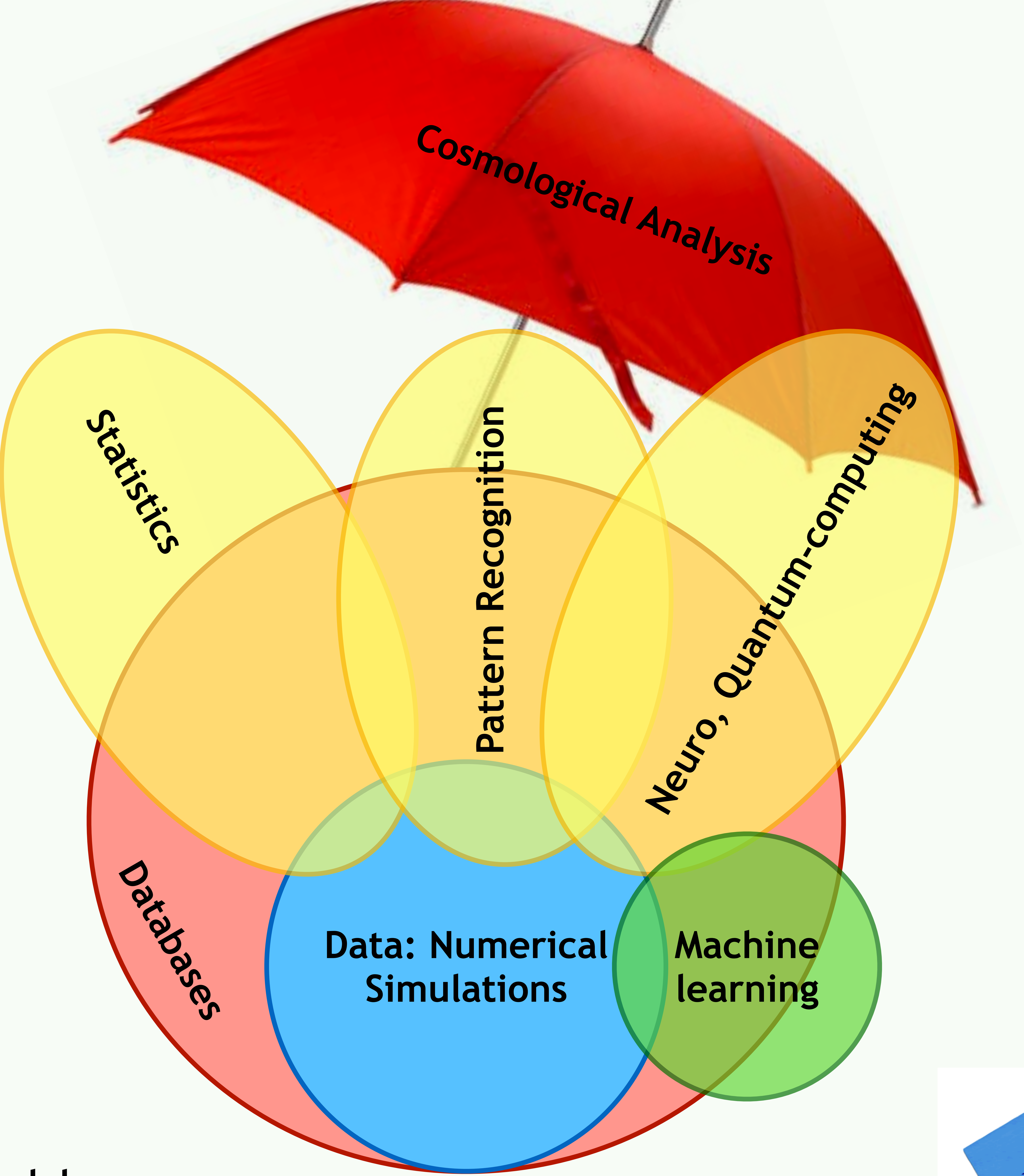

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