The impact of baryons on weak lensing statistics

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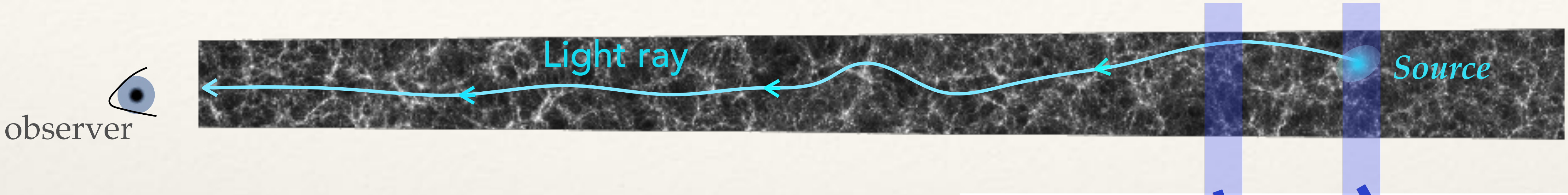
22/10/2018 - Euclid - France atelier workshop gravitational lensing

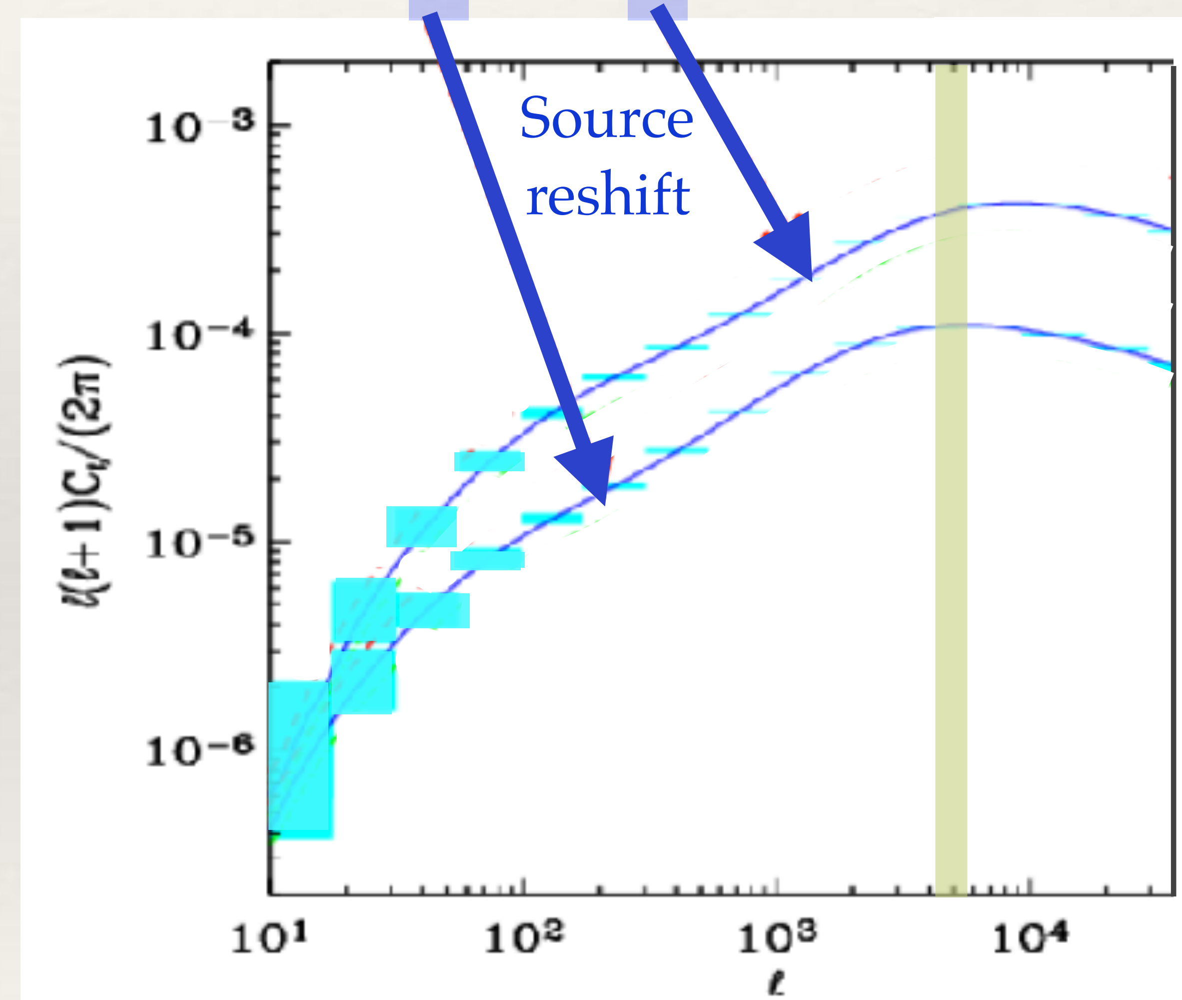
Cosmic shear: weak lensing by the large scale structure

the upcoming large weak lensing galaxy survey from Euclid



Euclid mission - Cosmic Shear
over 0 < z < 2
over 15,000 deg2

1.5 billion galaxy shapes,
accurate photometric redshifts



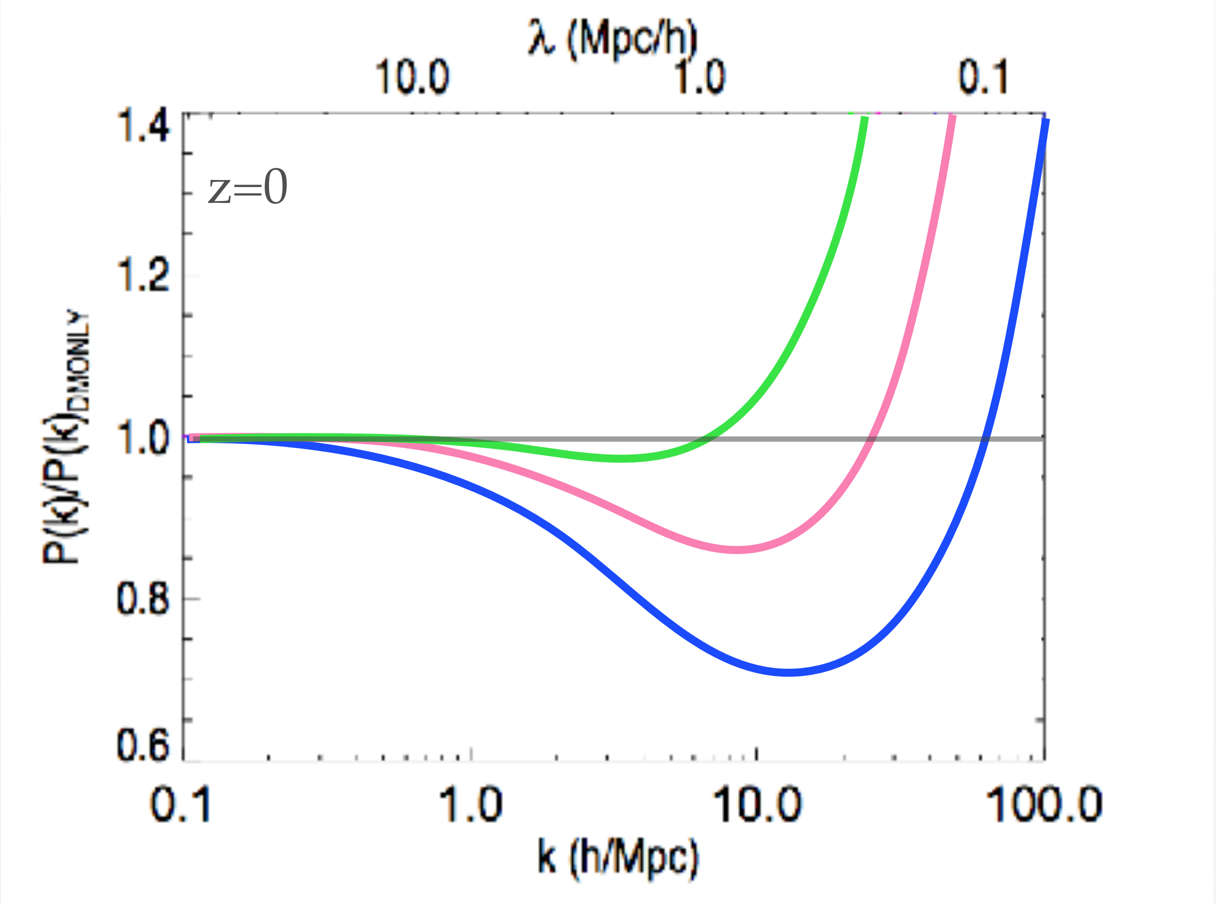
From Y. Mellier, 2013

Accurate theoretical model

$l_{\max} \sim 4000 \quad \theta_{\max} \sim$ few arcmin

The impact of baryons and baryonic physics on the matter power spectrum

Simulations OWLS



E. Semboloni, et al 2011

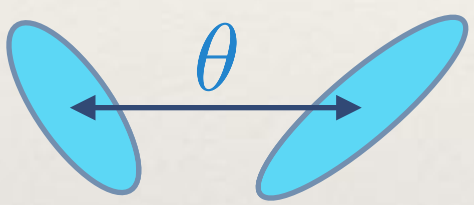
DARK MATTER

Hydrodynamical simulation
Gas cooling,
Star formation & évolution,
SN feedback

Same changing the initial stellar mass function

Same adding AGN feedback

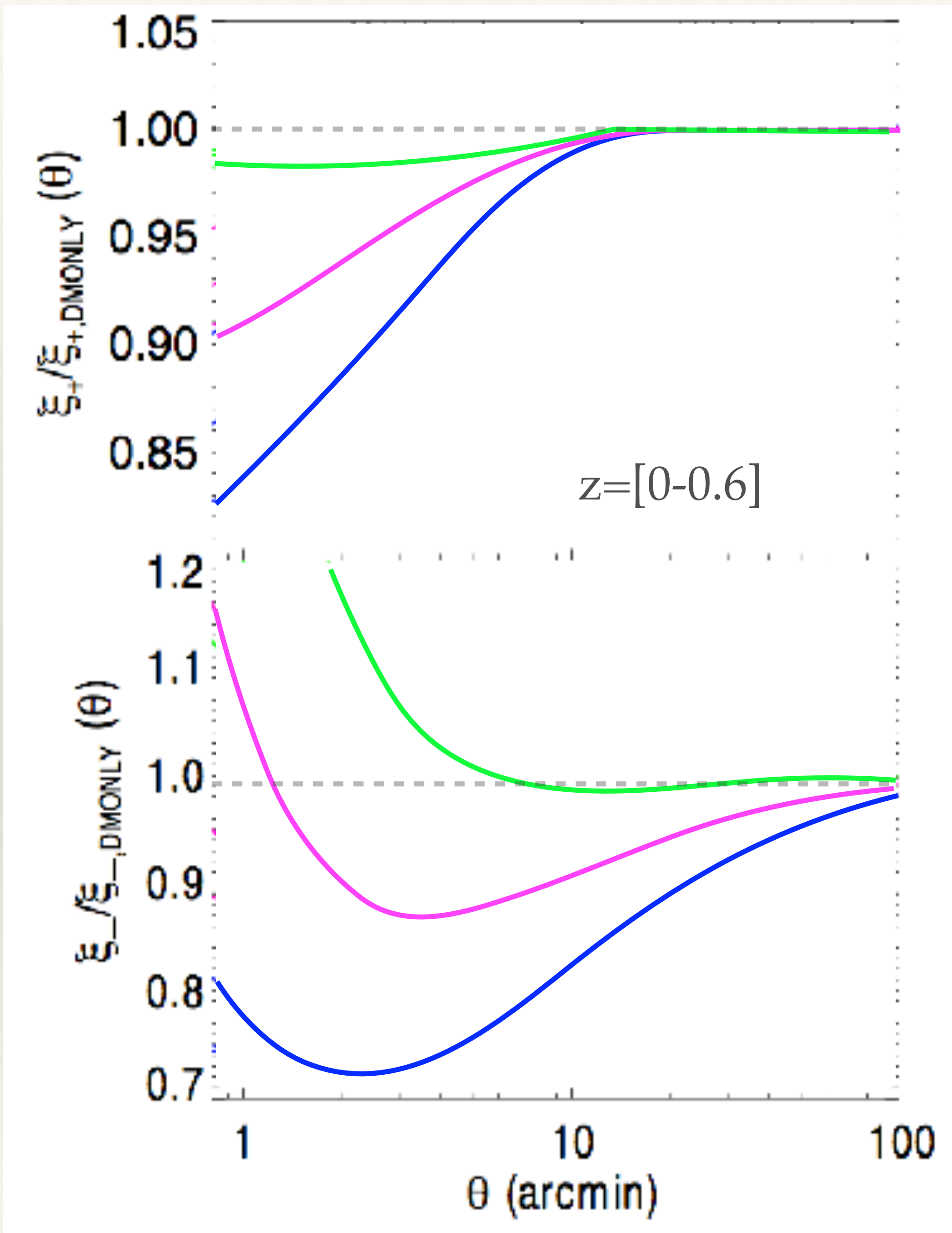
The impact of baryons and baryonic physics on the weak lensing statistics



2-point shear correlation function

$$\xi_{\pm}(\theta) = \langle \epsilon_+ \epsilon_+ \rangle(\theta) \pm \langle \epsilon_\times \epsilon_\times \rangle(\theta)$$

Simulations OWLS



E. Semboloni, et al 2011

DARK MATTER

Hydrodynamical simulation
Gas cooling,
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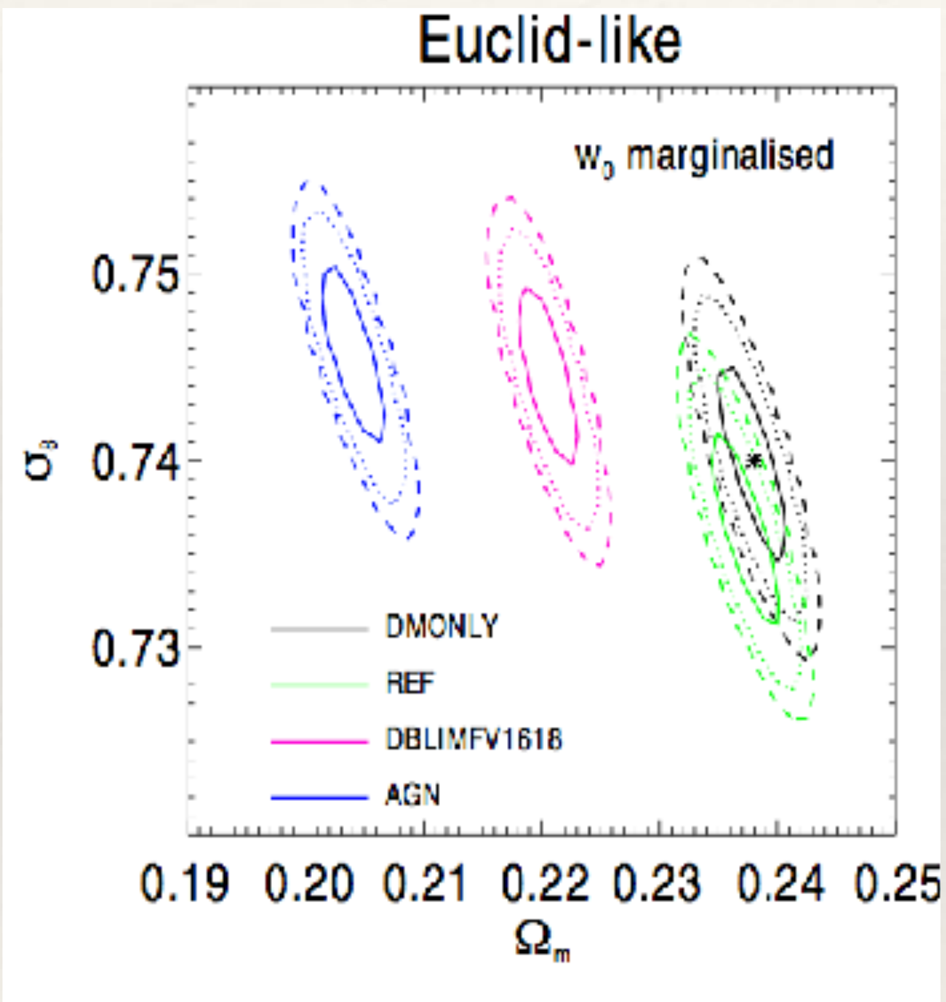
SN feedback

Same changing the initial stellar mass function

Same adding AGN feedback

The impact of baryons and baryonic physics on the corresponding cosmological constraints

Simulations OWLS

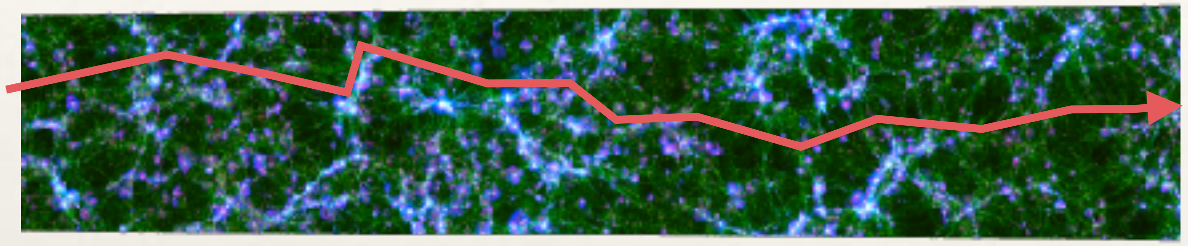


E. Semboloni, et al 2011

Ignoring baryons can bias cosmological constraints

- DARK MATTER
- Hydrodynamical simulation
- changing IMF
- + AGN feedback

Ray-tracing through the light-cone of Horizon-AGN simulation



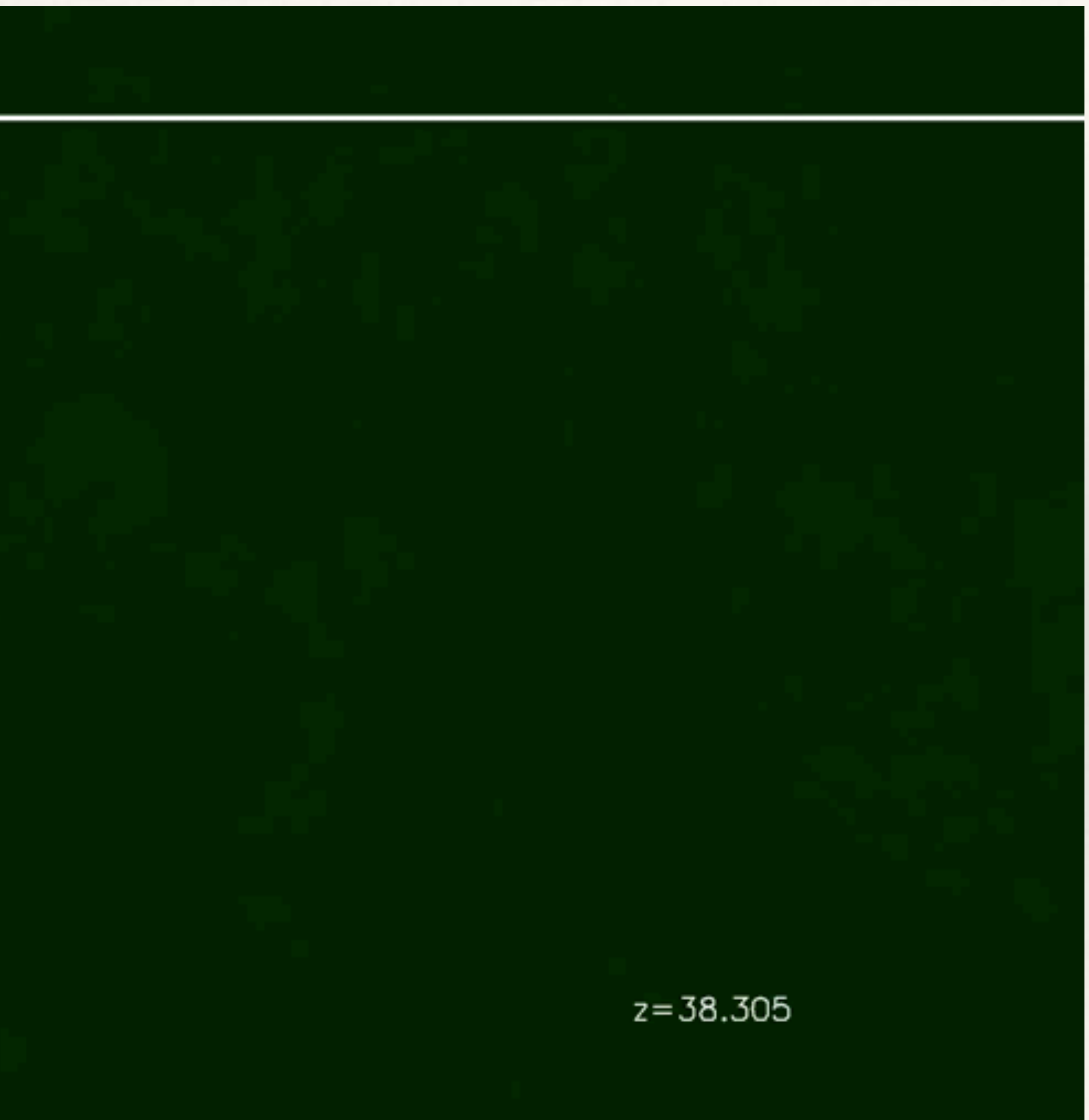
light ray propagation method

The impact of the baryons on the weak lensing statistics

(Gouin et al 2018, submitted to A&A)

- We predicted the lensing signal by **propagating light-rays** through the **light-cone of the Horizon-AGN** hydrodynamical simulation down to small scales
- We quantified the **impact of baryons on the two point statistics of weak lensing observables**
- We explored the relation between **galaxies and mass** by comparing Galaxy-Galaxy lensing signal with current observations

Horizon-AGN simulation



Dubois et al, 2014

Run with Adaptive Mesh Refinement code RAMSES (Teyssier, 2002)

L_{box} = 100 Mpc/h

1024^3 DM particles

Mass resolution $M_{res,DM} = 8\ 10^7\ M_\odot/h$

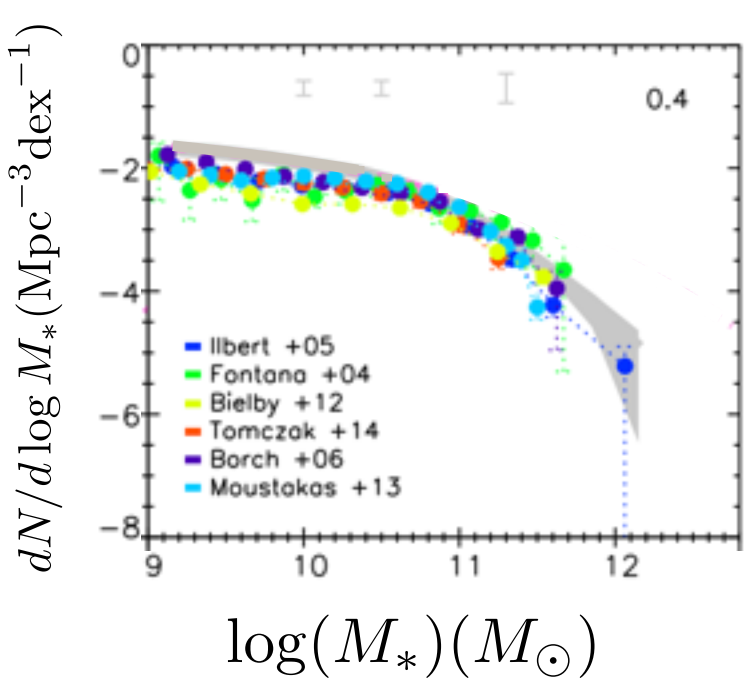
Spatial resolution $\Delta x = 1$ kpc

Simulated baryonic processes

- ✓ Gas dynamics
- ✓ Gas heating / cooling
- ✓ Star formation
- ✓ Feedback of SuperNovae
- ✓ Feedback of Active Galactic Nuclei

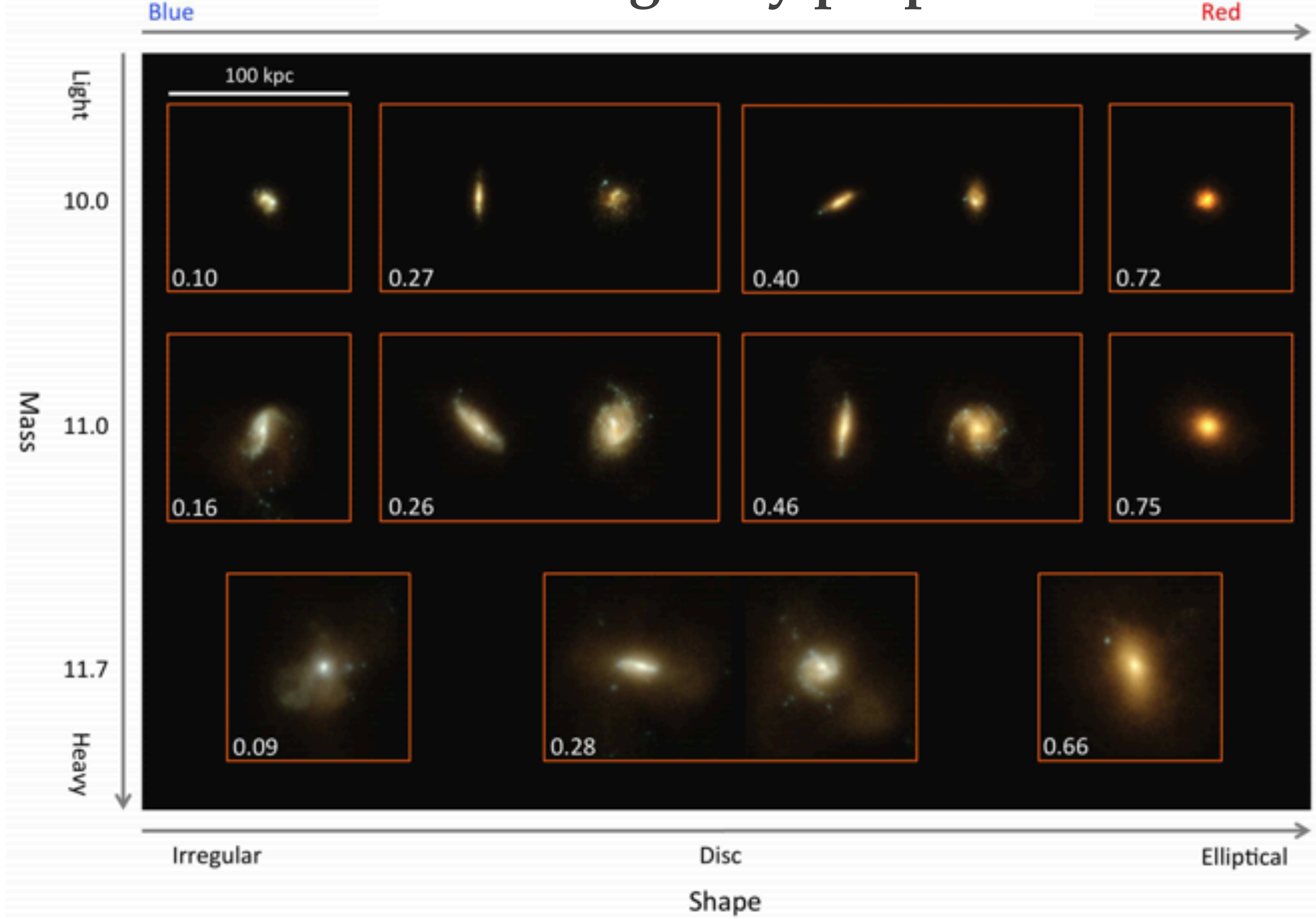
Horizon-AGN simulation

Stellar mass function



(Kaviraj et al. 2017)

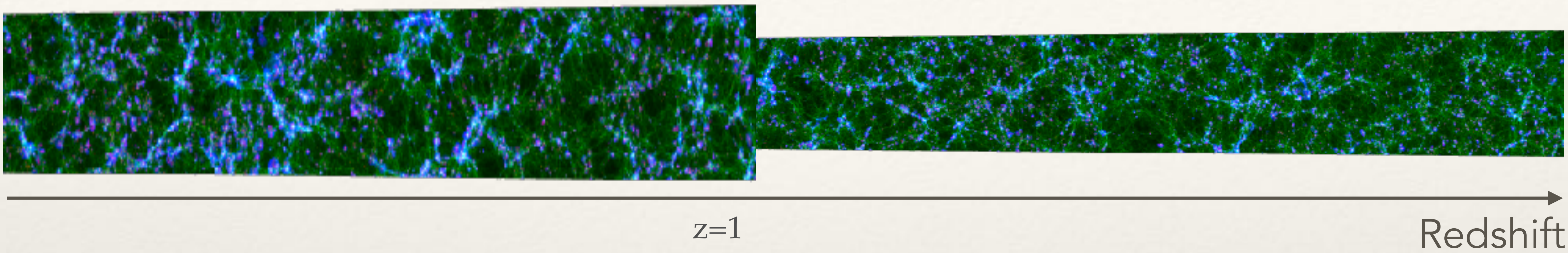
Realistic galaxy properties

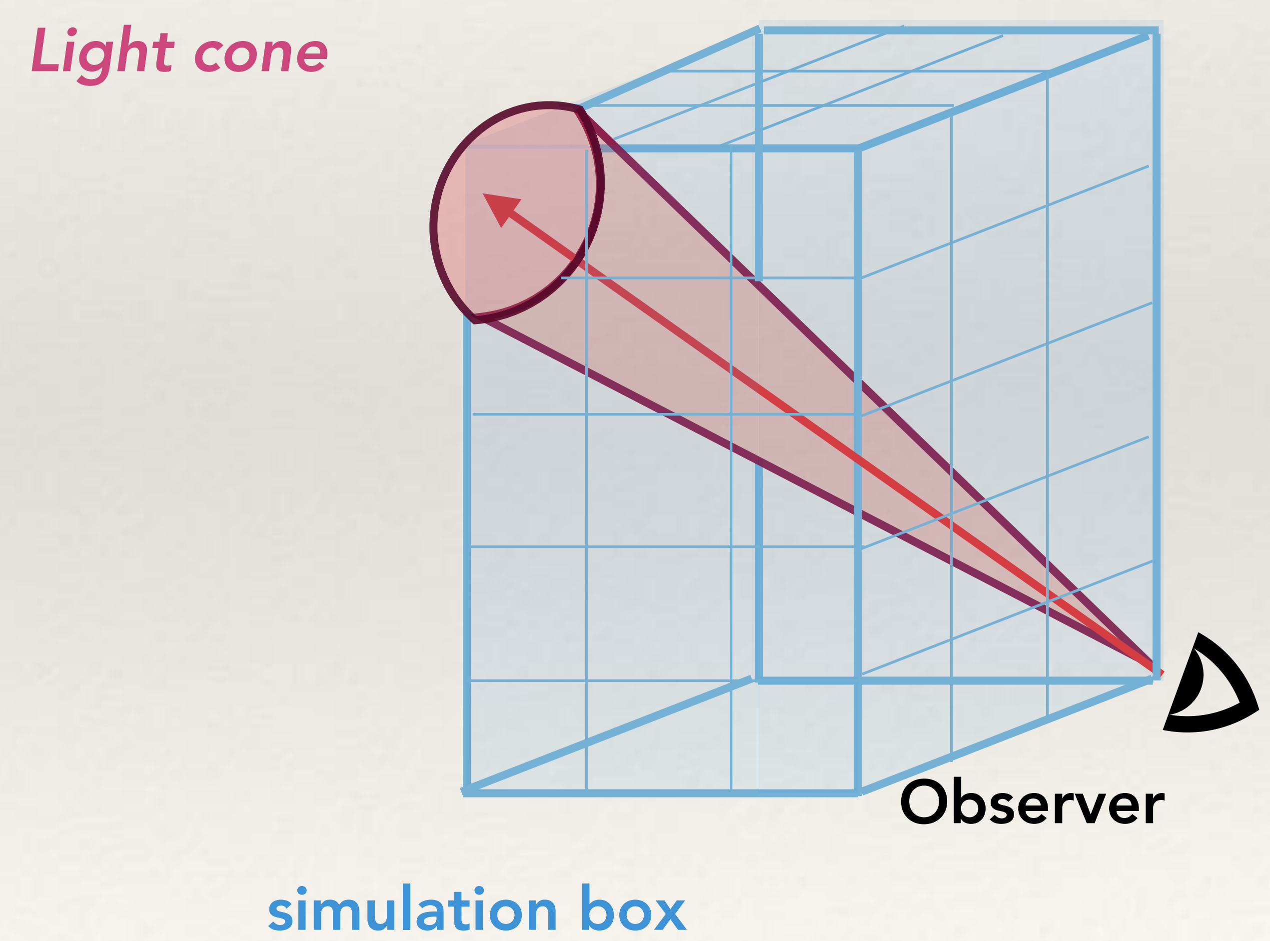


Stellar emission of a sample of galaxies at z = 1.3 observed through rest-frame u, g and i filters.

(Dubois et al, 2014)

The light-cone of Horizon-AGN simulation





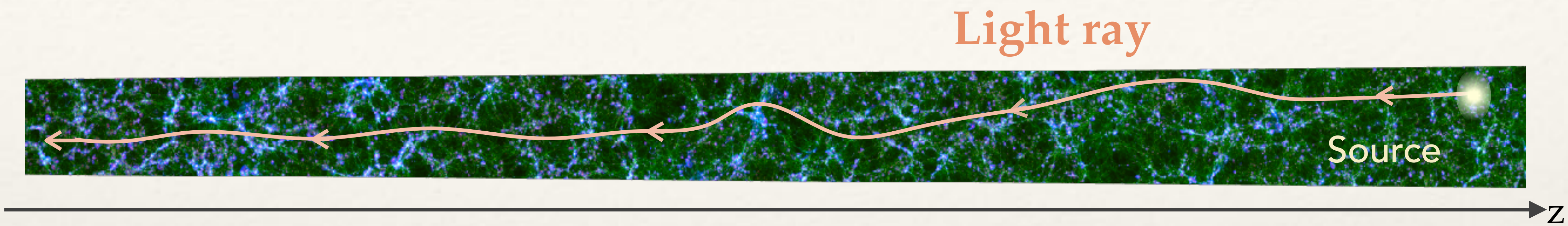
The light-cone is extracted on-the-fly

- ✓ 5 square degrees until z~1
- ✓ 1 square degree until z~7

Propagation of light rays

Theory

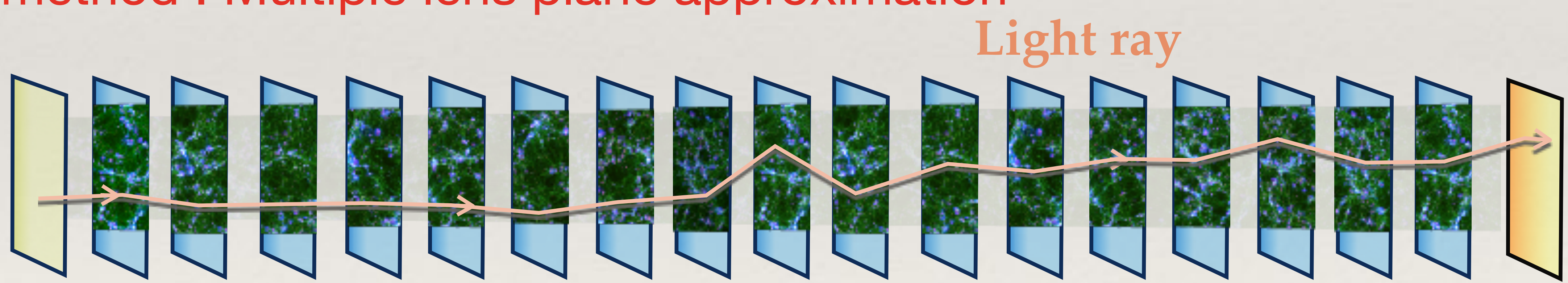
observer



continuous $$\vec{\beta} = \vec{\theta} - \frac{2}{c^2}\int_0^{\chi_s} d\chi \frac{\chi_s - \chi}{\chi_s\ \chi} \vec{\nabla}\phi\left(\vec{\beta},\chi\right)$$

Numerical method : Multiple lens plane approximation

observer



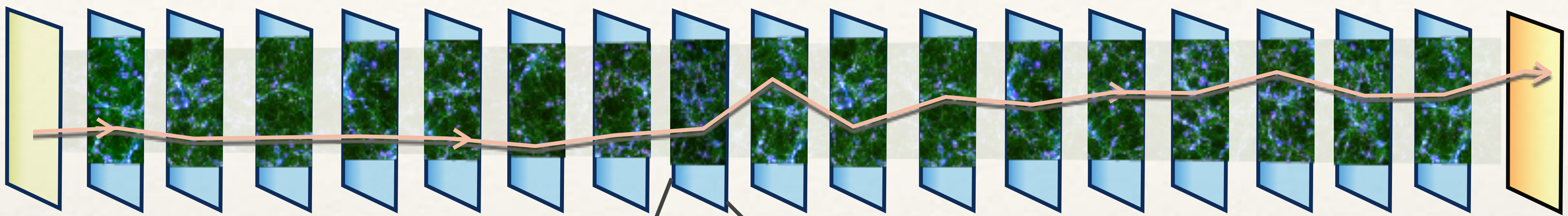
Source plane

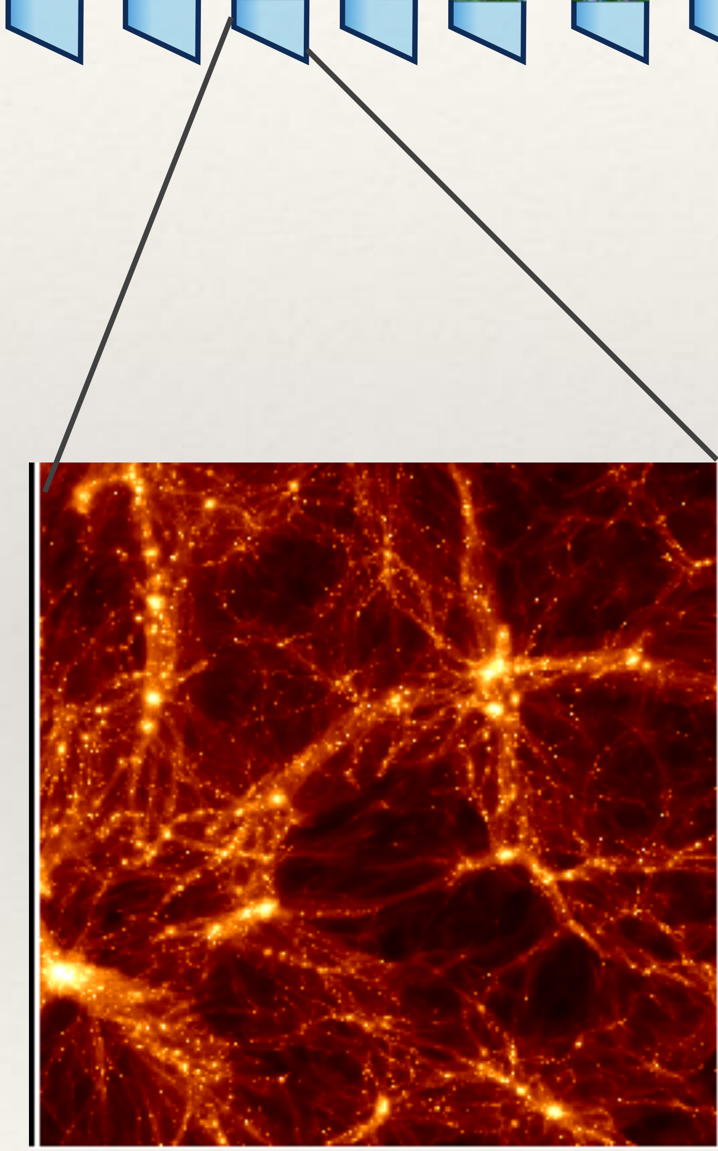
The light rays are traced back from the observer to a fiducial source plane

500 lens planes up to z~7

discrete $$\vec{\beta}^j = \vec{\theta} - \sum_{i=1}^{j-1} \frac{D_{i;j}}{D_j}\vec{\alpha}^i(\vec{\beta}^i)$$

Computing the deviation of light rays on each lens plane





Mapping the surface density (SPL)

Standard approach

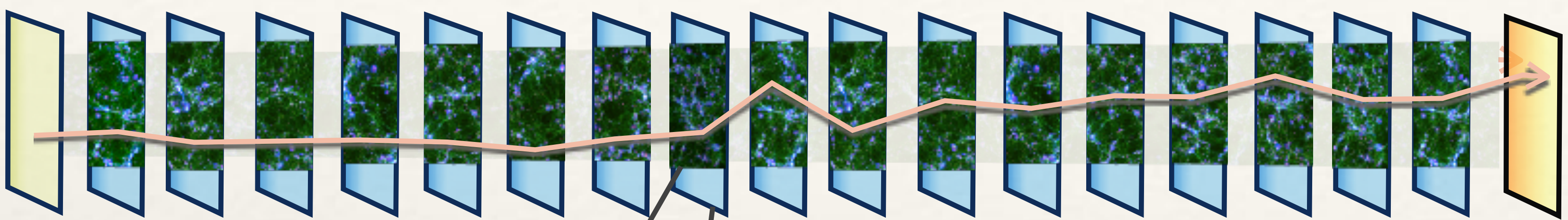
pros	separate components
cons	edge effect (FFT)

Using the acceleration field (OBB)

New approach

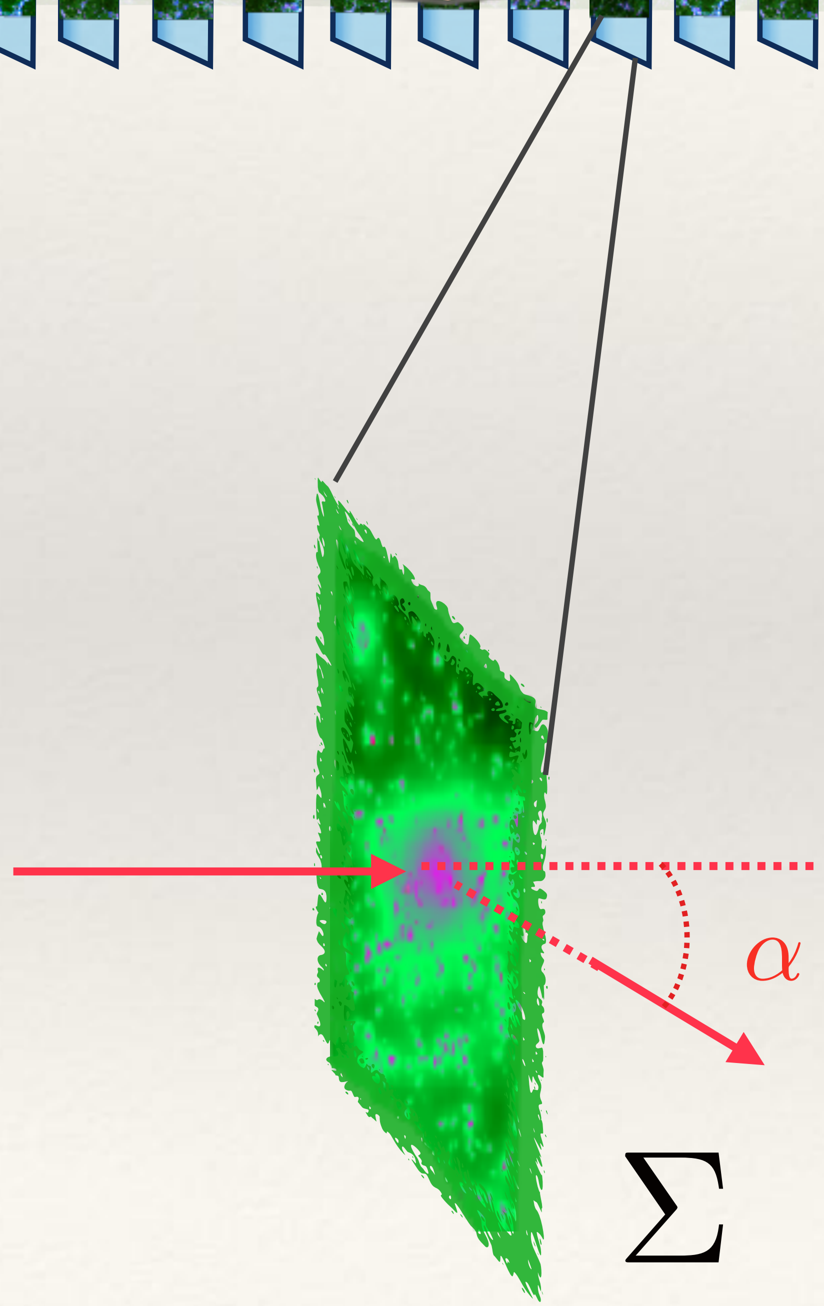
pros	integrate the true acceleration
cons	do not separate components

Computing the deviation of light rays on each lens plane (SPL)



The deflection

$$\overrightarrow{\alpha} = \int \overrightarrow{\nabla} \phi \, dl$$



Mapping the surface density

2D Poisson equation $\Delta\phi = 4\pi G \Sigma$

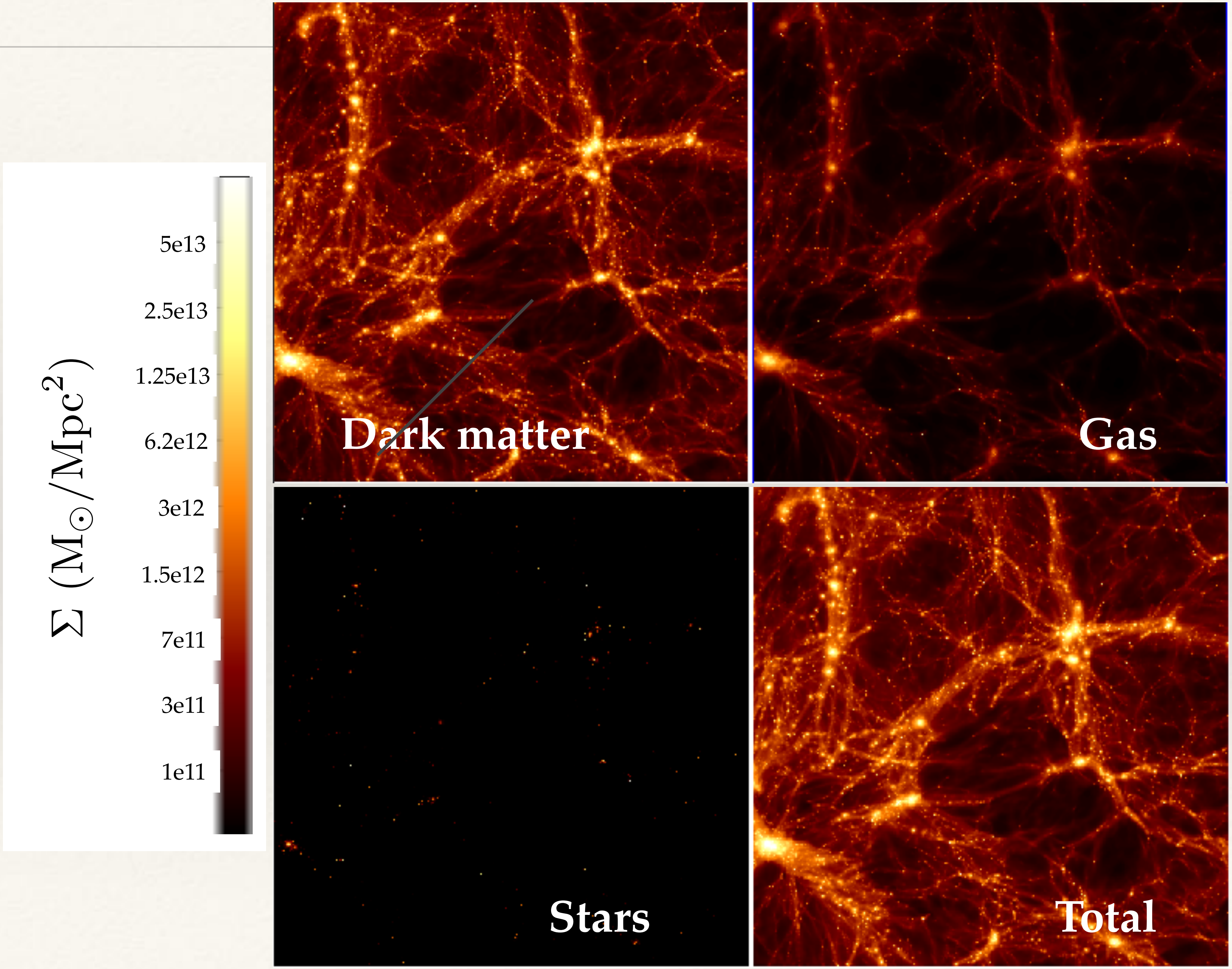
Each particle is smoothed by a **gaussian kernel** as function of the **local density**

Inspired by the Smooth Particle Lensing method (Aubert et al, 2007)

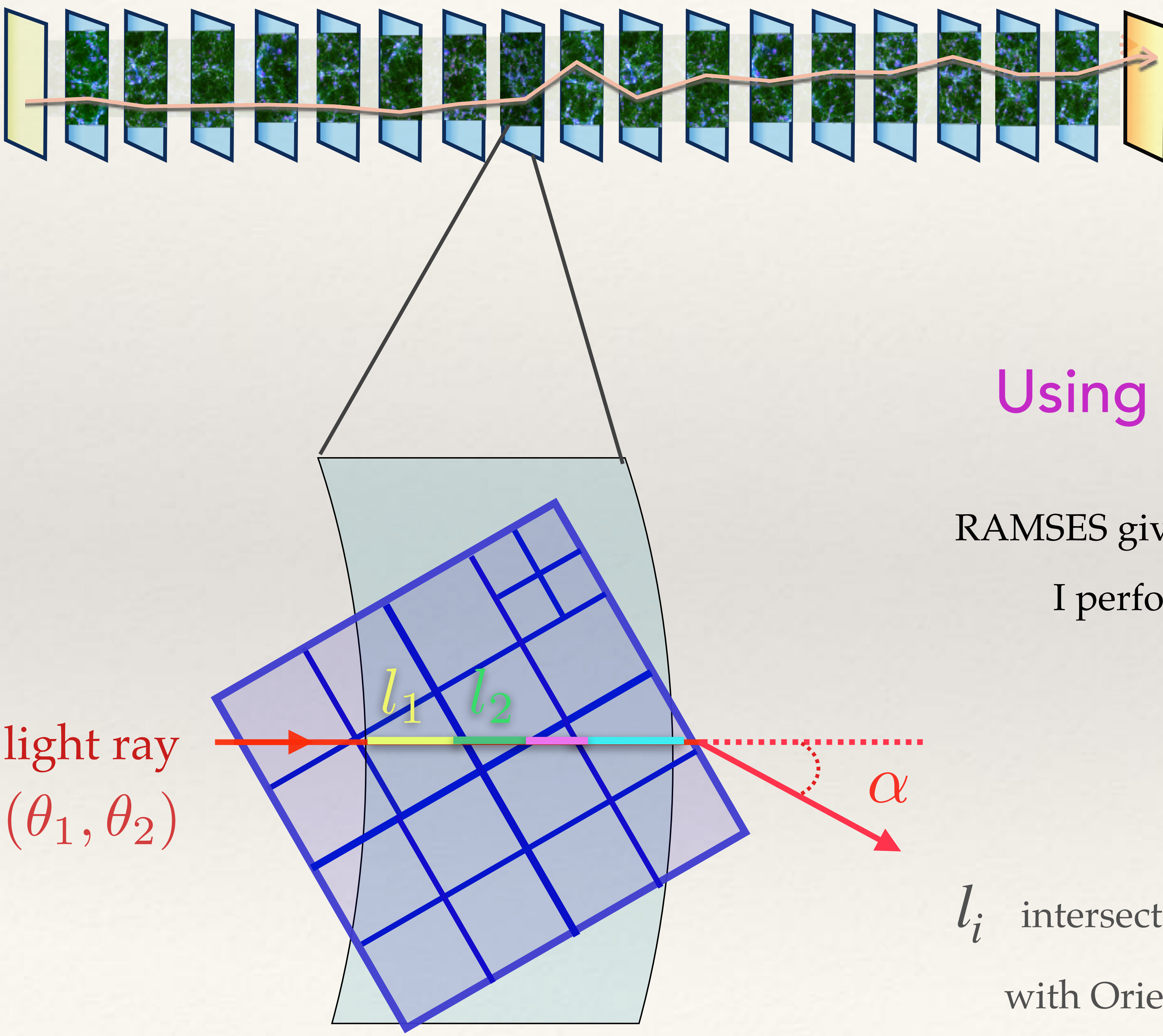
Computing the deviation of light rays on each lens plane (SPL)

One lens plane at z~0.4

field of view 2.25x2.25 deg2



Computing the deviation of light rays on each lens plane (OBB)



The deflection

$$\overrightarrow{\alpha} = \int \overrightarrow{\nabla} \phi \, dl$$

Using the acceleration field

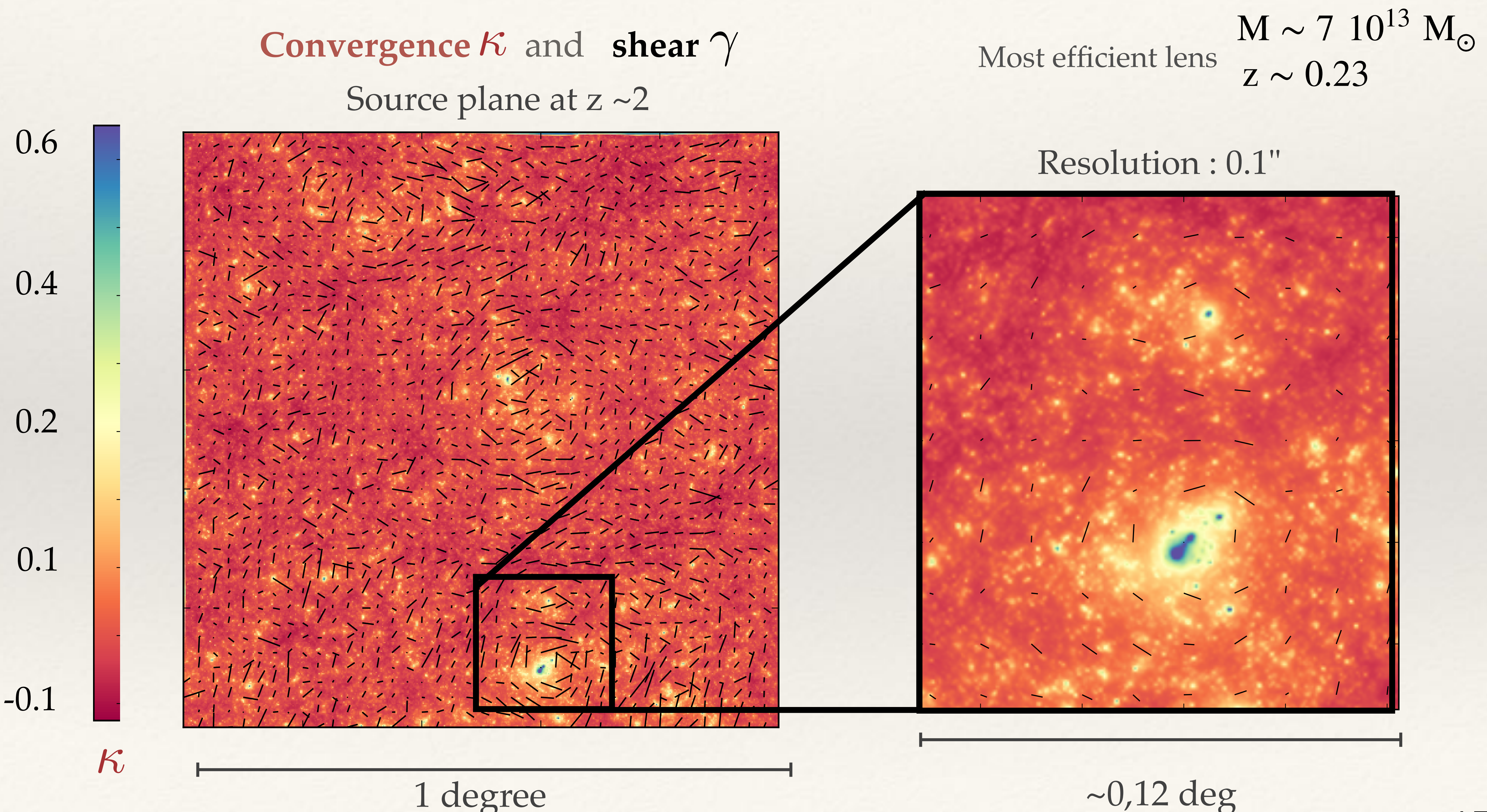
RAMSES gives the acceleration field for each cell.

I perform the deflection by summing:

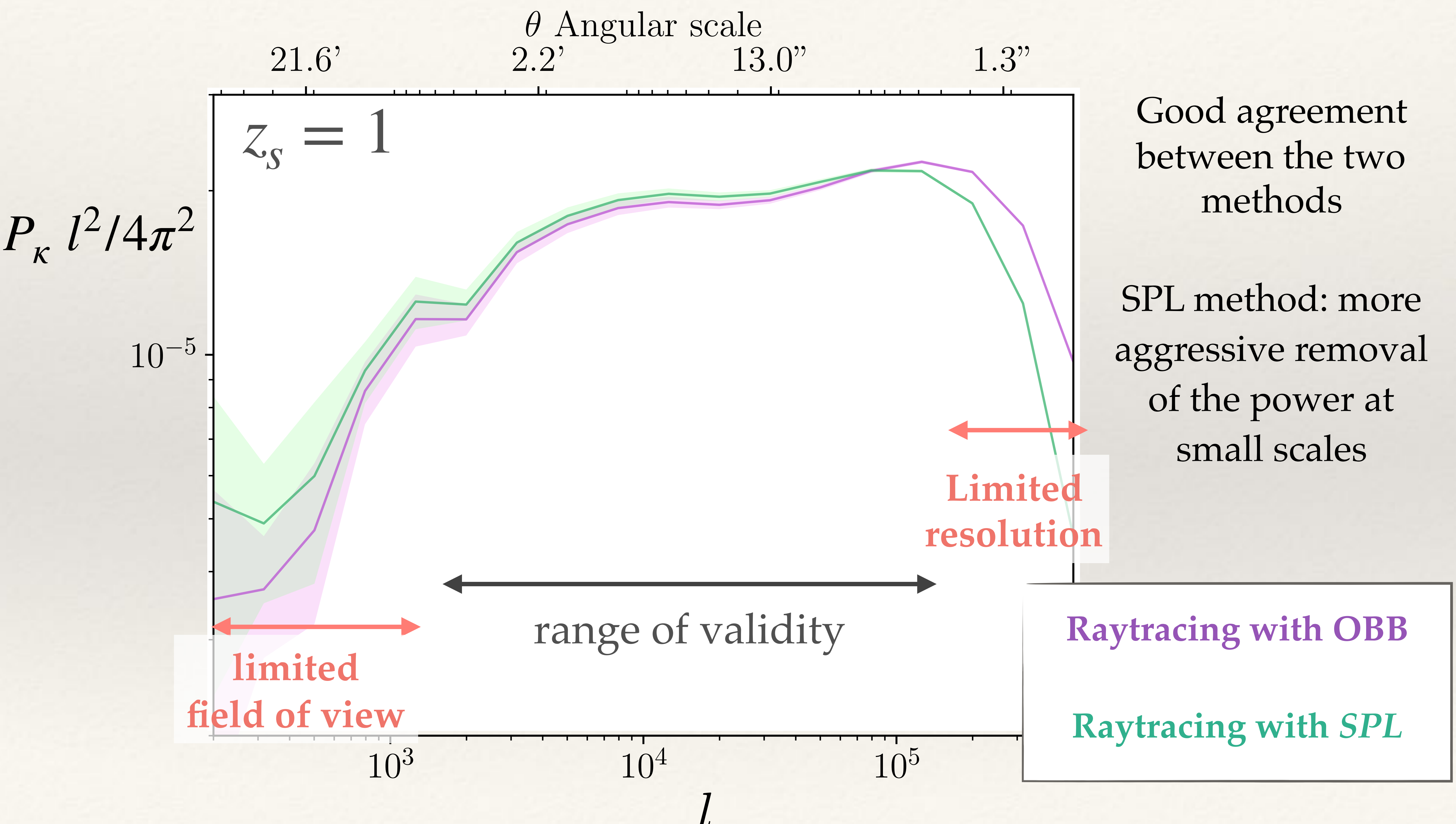
$$\vec{\alpha}(\vec{\theta}) \propto \sum_{i_{cells}} \vec{a_i} \; l_i$$

l_i intersection between a ray and a cell obtained with Oriented Box Boundary method (**OBB**)

High resolution maps (by OBB method)



The convergence power spectrum

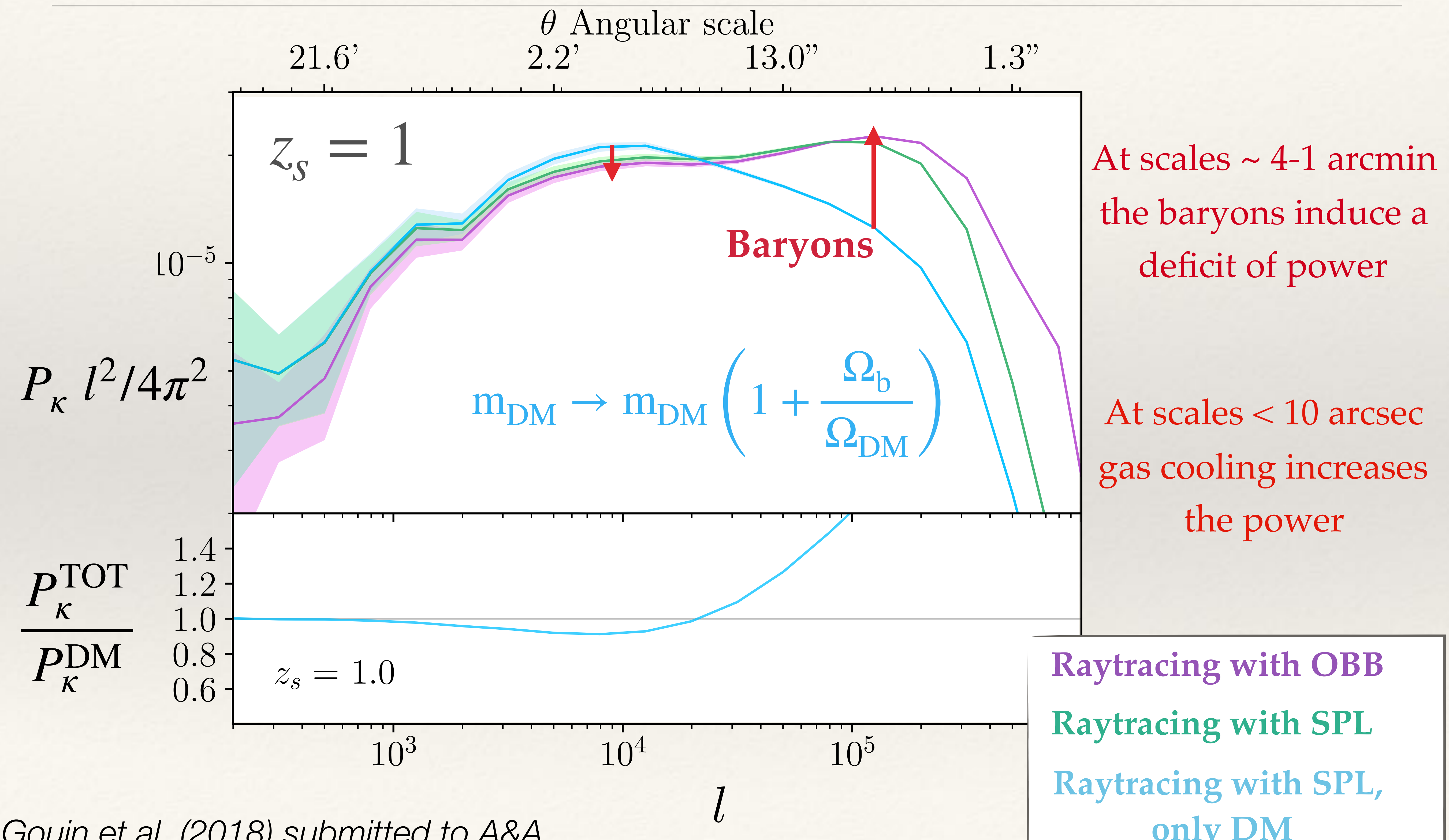


Good agreement between the two methods

SPL method: more aggressive removal of the power at small scales

Gouin et al. (2018) submitted to A&A

The impact of baryons on the convergence power spectrum

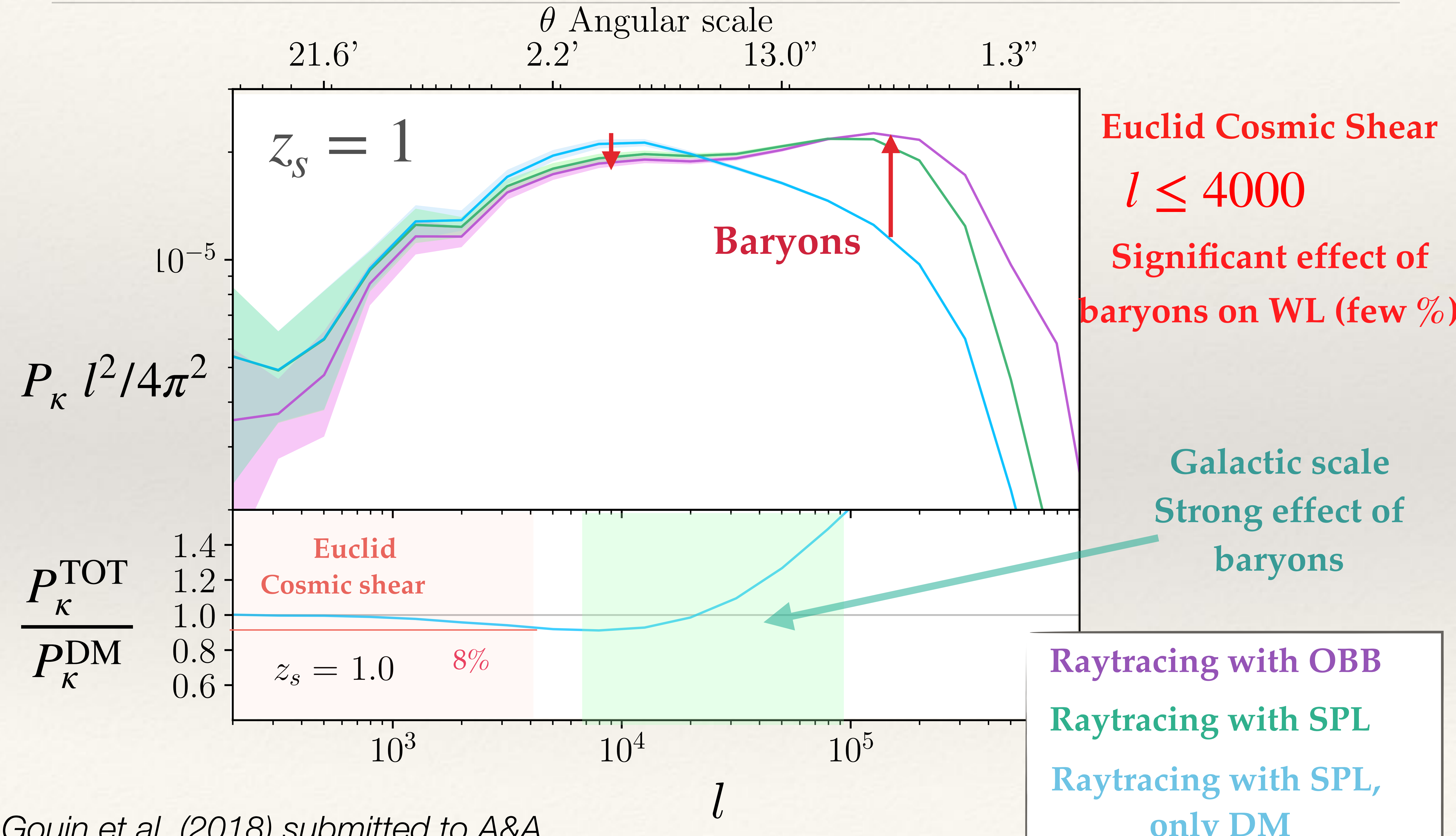


At scales ~ 4-1 arcmin the baryons induce a deficit of power

At scales < 10 arcsec gas cooling increases the power

Gouin et al. (2018) submitted to A&A

The impact of baryons on the convergence power spectrum



Gouin et al. (2018) submitted to A&A

Galaxy-Galaxy lensing (GGL)

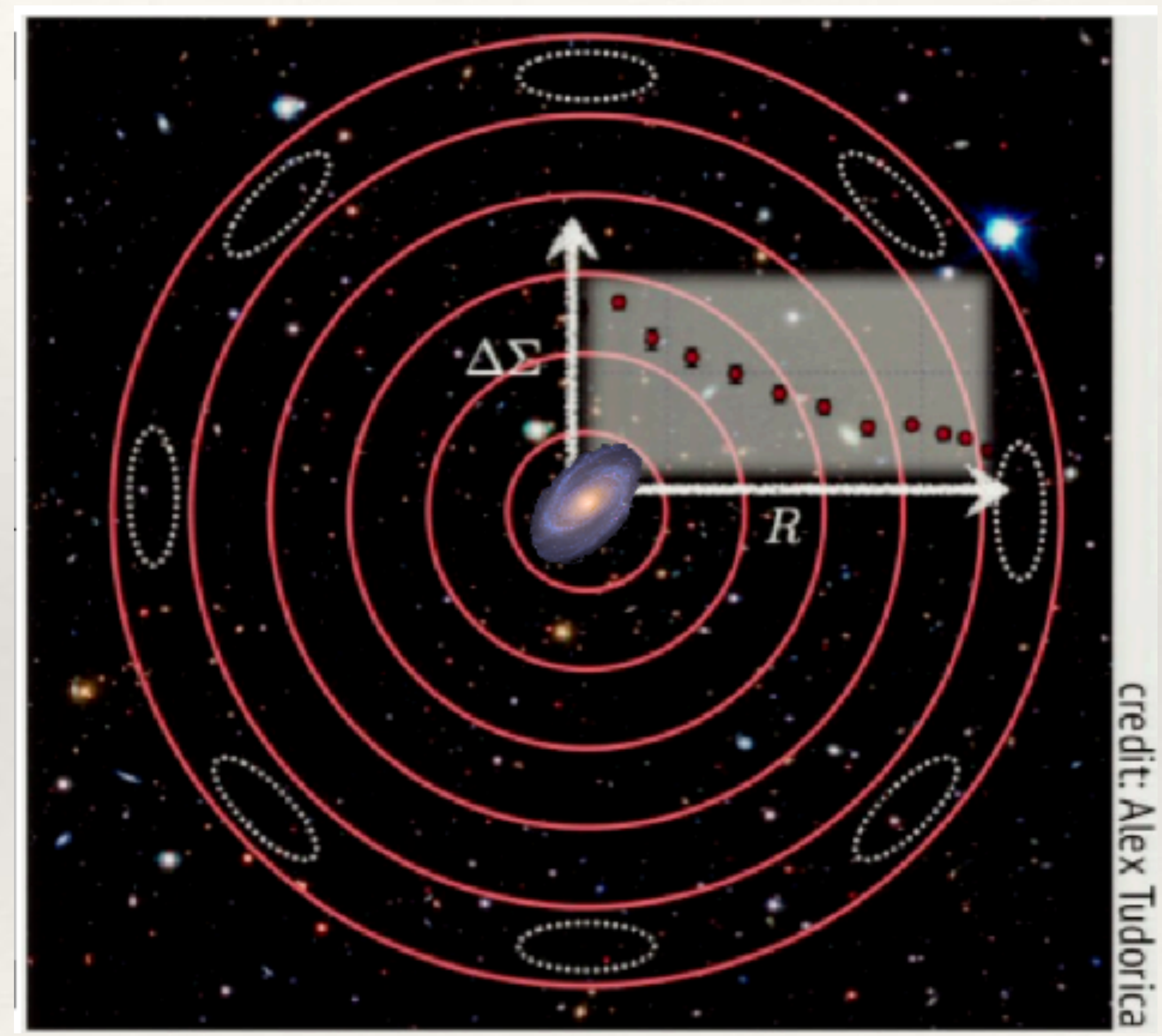
The excess surface mass density

$$\Delta\Sigma(R) \propto \gamma_T(R)$$

$$\Delta\Sigma(R) = \frac{M(<R)}{\pi R^2} - \Sigma(R)$$

Galaxy-Galaxy lensing is used to probe:

- the galaxy-halo connection
- the projected density at galactic scales



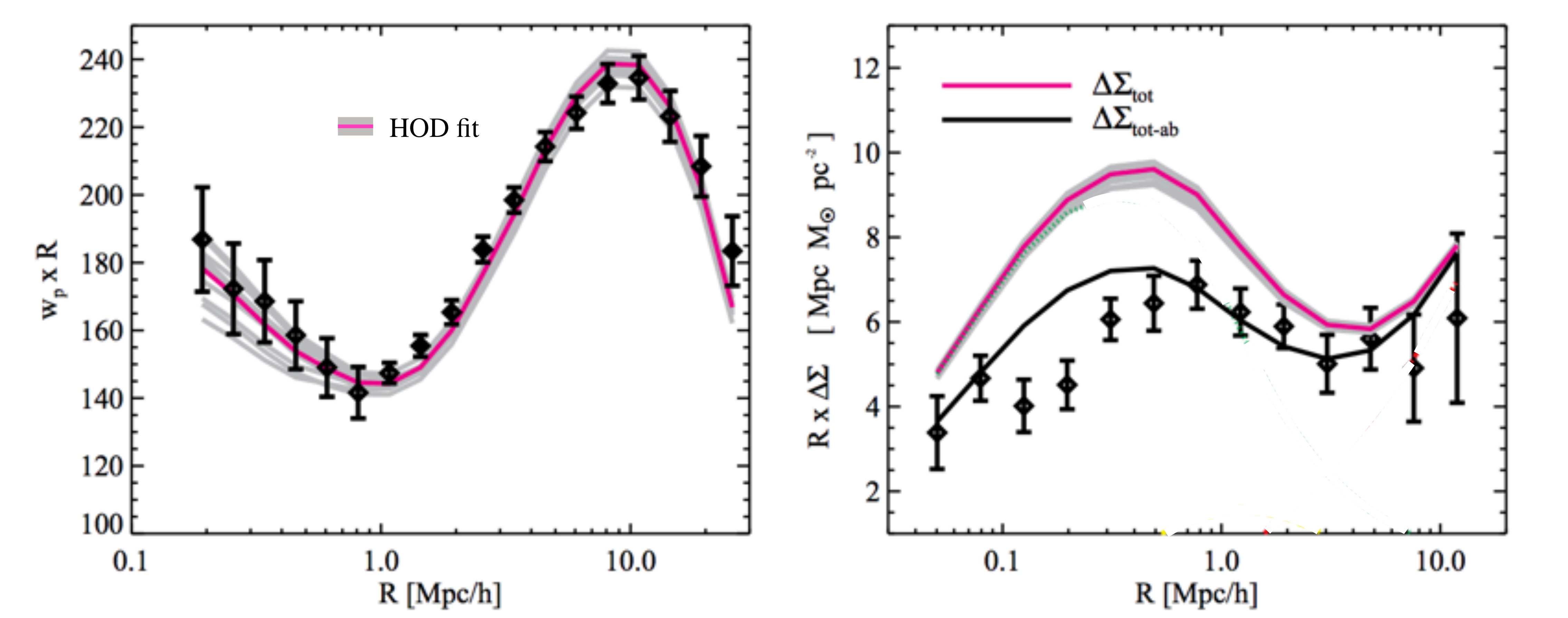
Estimation of γ_T by averaging galaxy ellipticities in concentric annuli centred on the lens

GGL: comparison between Horizon-AGN and observations

The lens Galaxy sample of Leauthaud et al. (2016)

- the CMASS (BOSS) lens galaxy sample
- $M_* > 1.7 \times 10^{11} \ M_\odot$
- $z_L \in [0.4 - 0.7]$

GGL and clustering of galaxies are compared with prediction from HOD models



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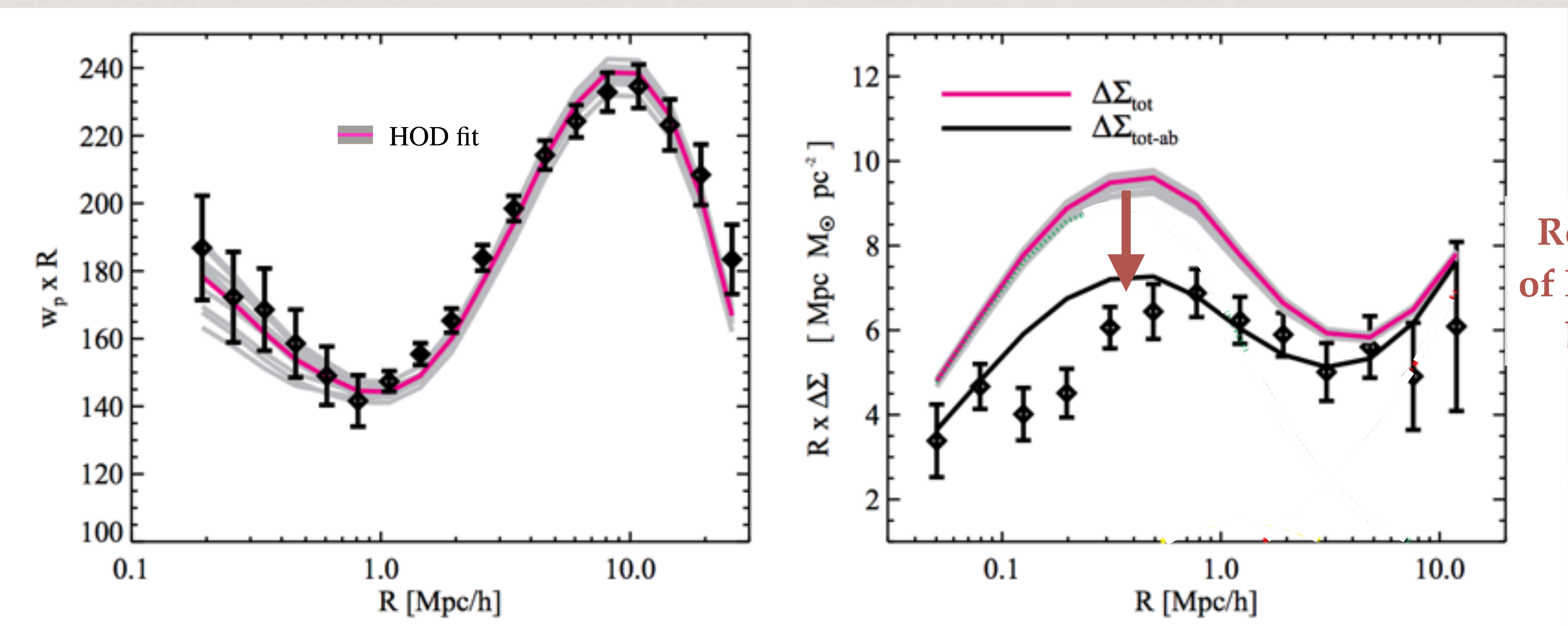
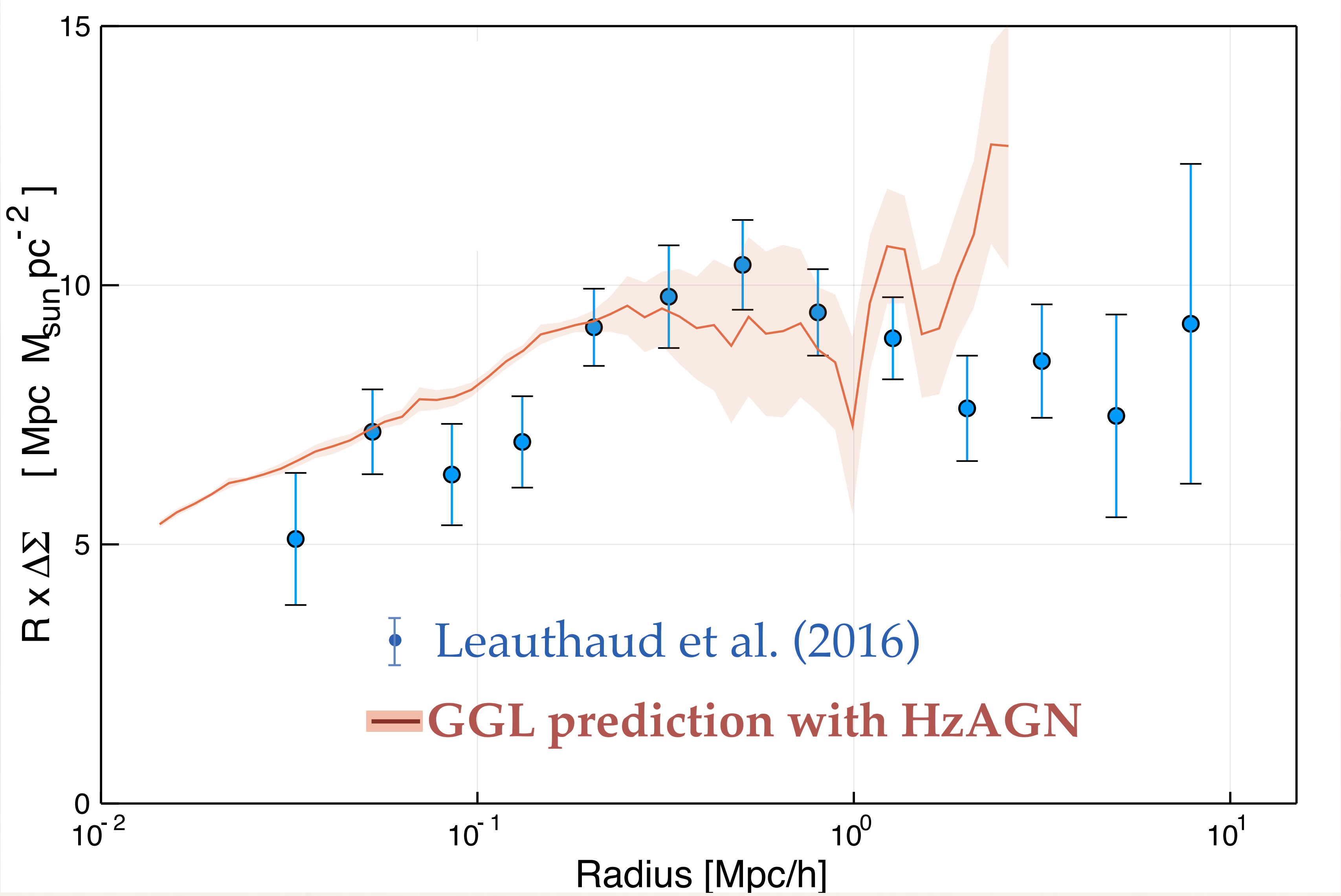


Reduction of halo mass by 35%

GGL: comparison between Horizon-AGN and observations

Similar shear profile as CMASS galaxies

This good agreement suggests that Horizon-AGN galaxies live in halos of the right mass

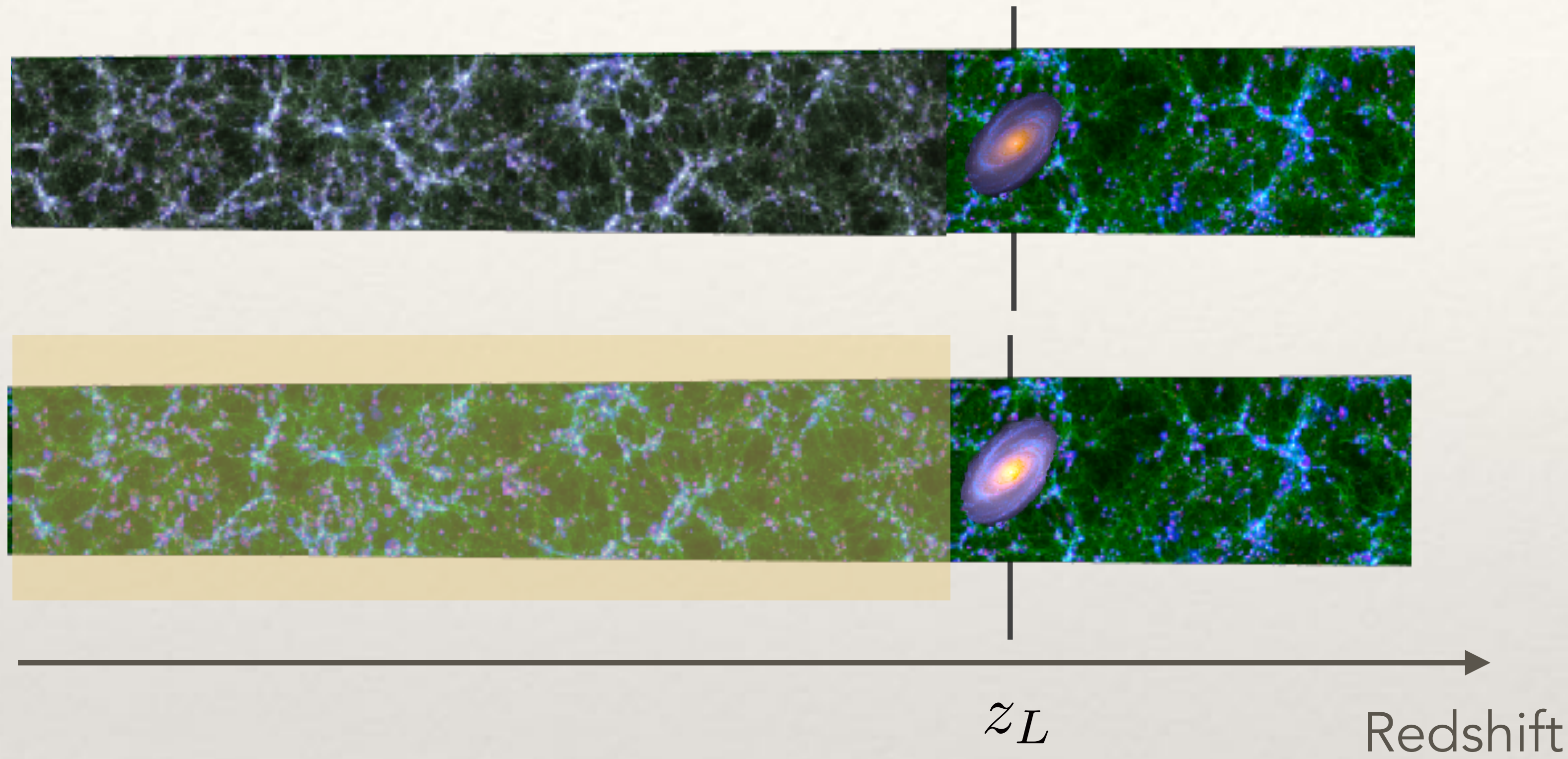


Limitation:
We could not assert that Horizon-AGN simulation has the right clustering amplitude

(scarse massive galaxies in small volume)

…GGL predictions by dark matter only, in process

The impact of magnification bias on GGL signal



Magnification of the lens

induced by the matter between the lens and the observer

From the extracted catalog of galaxies, magnification bias is applied to stellar mass of the galaxy

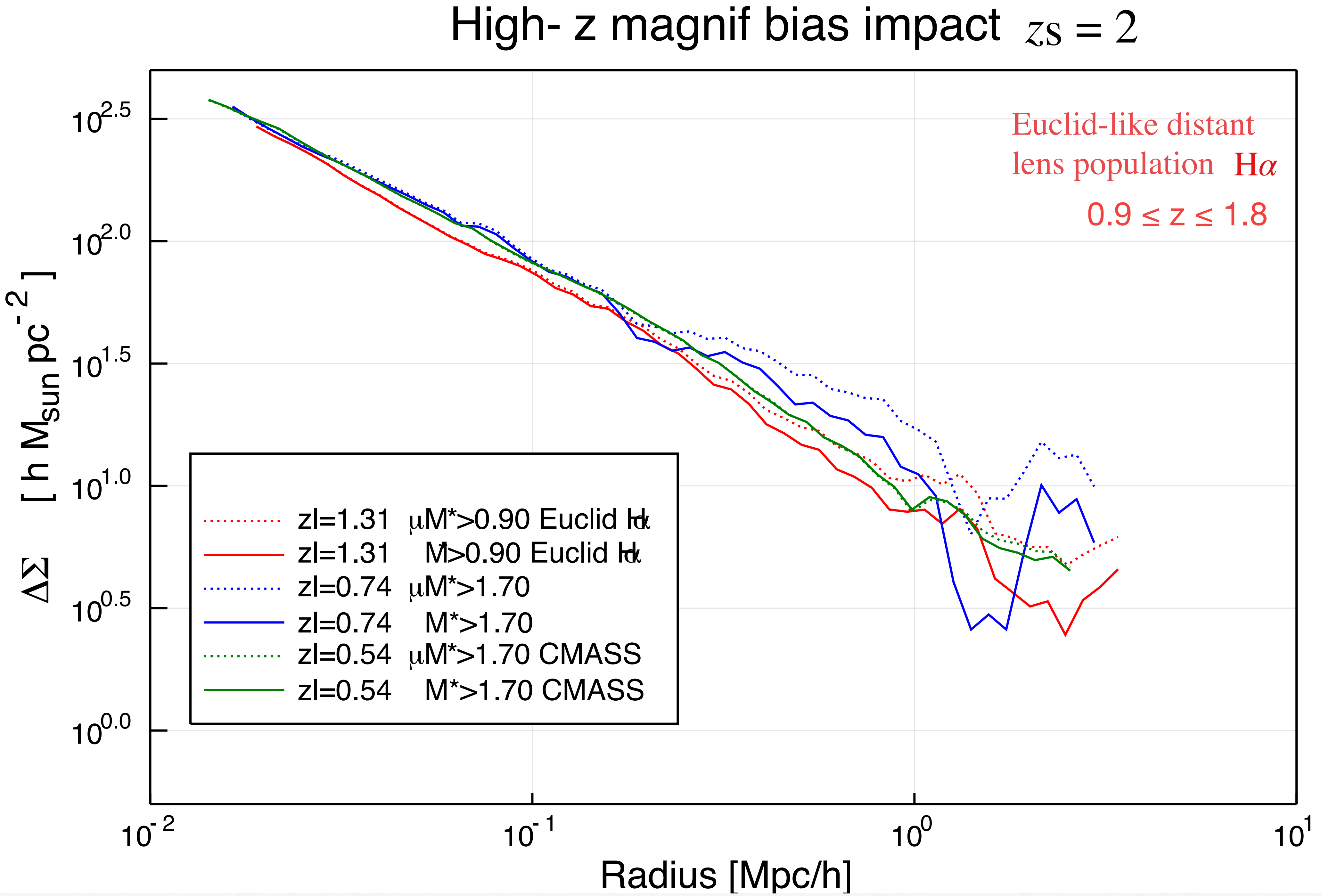
$$M_* \to \mu M_*$$

The impact of magnification bias on GGL signal

Magnification bias is applied to stellar mass

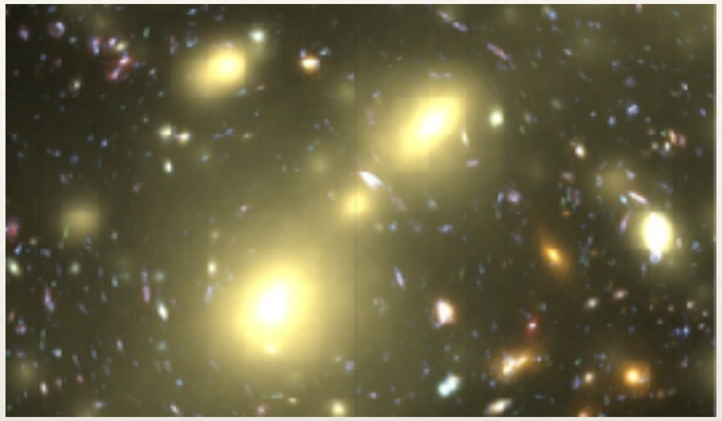
$$M_* \to \mu M_*$$

At higher redshift *z*>1, the impact of magnification bias on this correlation is relevant for separations greater than 1 Mpc.



See also Ziour & Hui (2008)

The production of mock lensed images



Realisation of mock lensed images

- Model the light emission of all star particles along the light-cone into a finit number of emitted source plane
- Lens the luminosity of source planes by the matter between them and the observer

Future: Adding observational noise and extracting galaxies properties (shape,redshift) with curent analyse pipelines

The production of mock lensed images

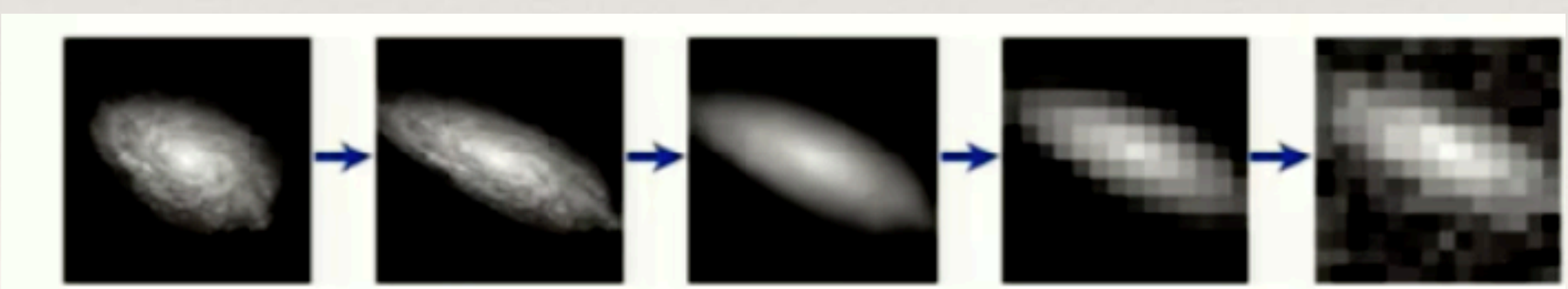
End-to-end comparison of signal:
From simulated galaxies to observations

Reproduce realistic observations of galaxies:

morphology and photometry, spatial distribution and lensing

Future investigation

➡ Quantify how well lensing signal can be recovered from observations



ϵ_s $\epsilon_s + \gamma$ PSF pixelisation noise

… blending, photometric redshift, intrinsic alignment

The production of mock lensed images

End-to-end comparison of signal:
From simulated galaxies to observations

Reproduce realistic observations of galaxies:

morphology and photometry, spatial distribution and lensing

Future investigation

➡ Quantify how well lensing signal can be recovered from observations

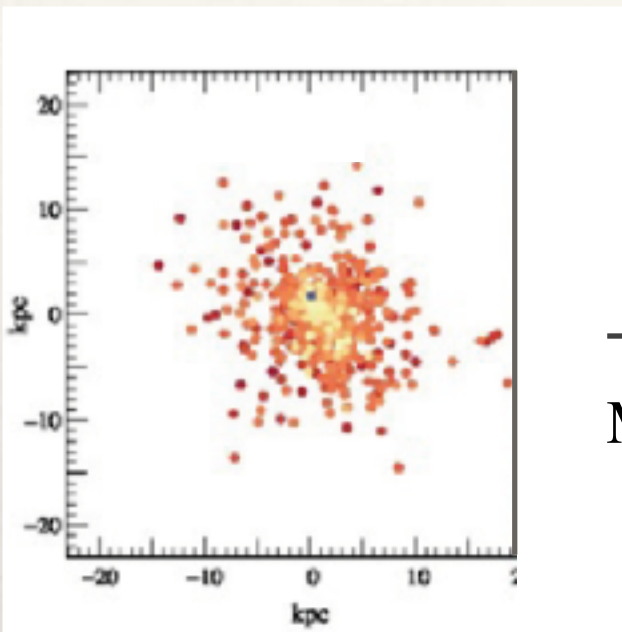
➡ Quantify the impact of lensing signal on observed galaxy properties

how lensing magnification biases 1-point statistics (the mass function)
magnification and displacement bias 2-point statistics (angular clustering)

Modelling light emission from star particles

Performed by C. Laigle

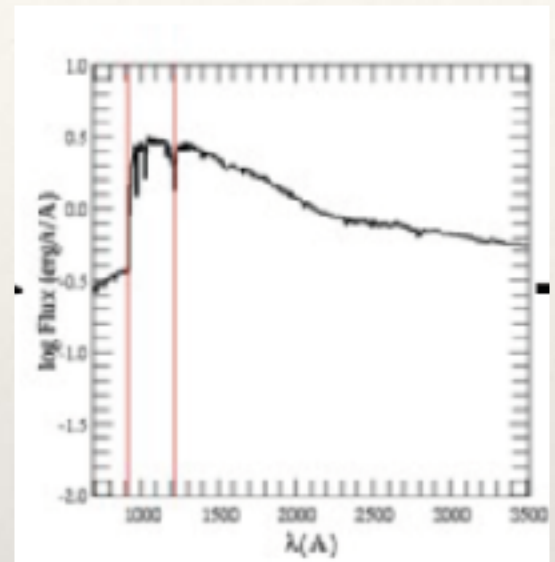
Star particle distribution



Age, mass, metallicity

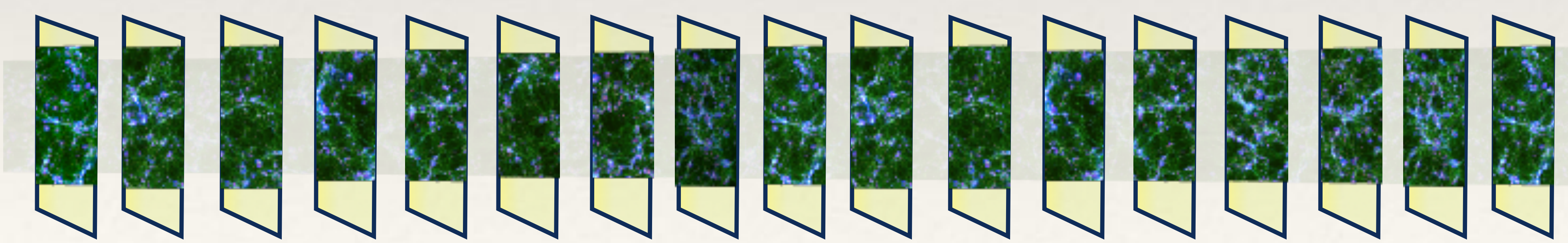
$M_* \sim 2\ 10^6\ M_\odot$

Spectral energy distribution



filter passband

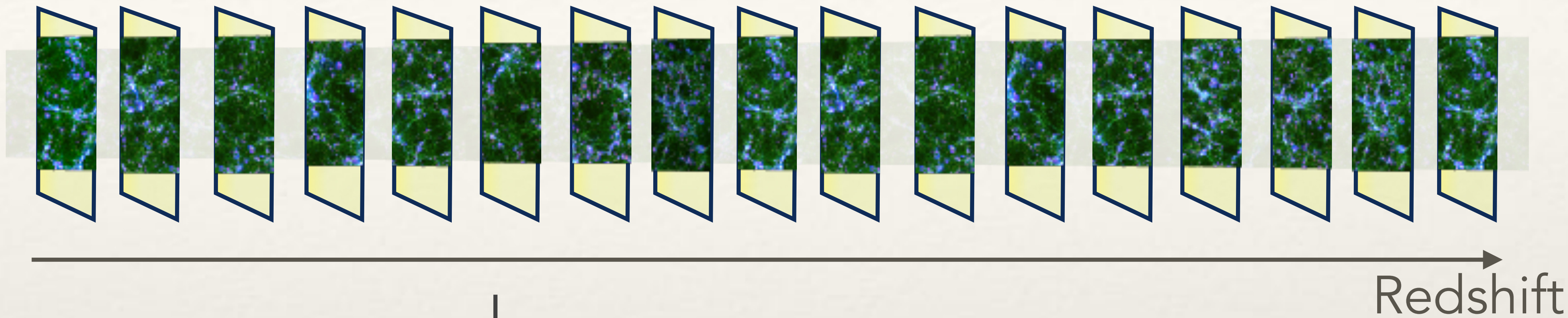
500 2D-Brightness maps (0.1 arcsec resolution) are made

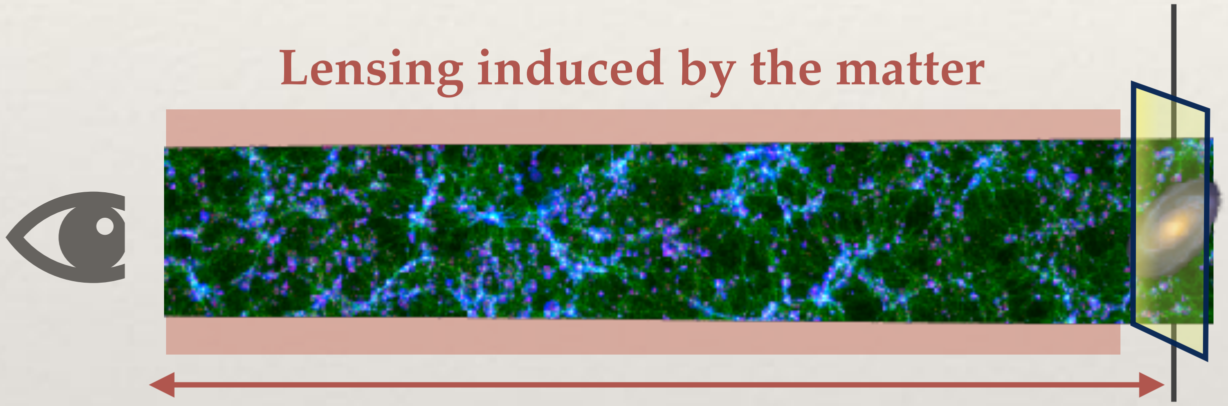


Redshift

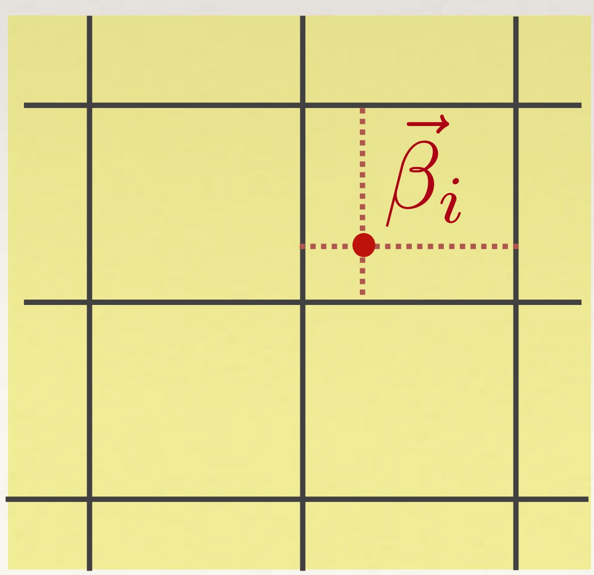
Distorting mock images

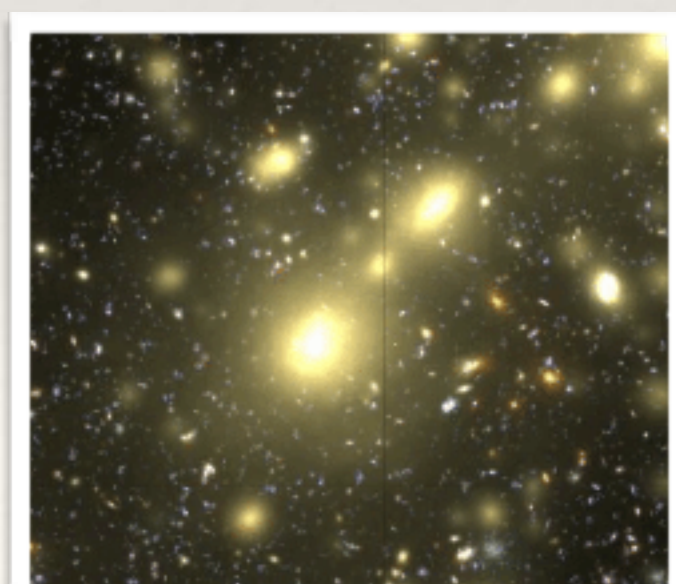
500
brightness
maps





$$I_s(\vec{\beta}_i = \vec{\theta}_i - \vec{\alpha}_i(\vec{\theta}_i)) \rightarrow I_s(\vec{\beta})$$





Conservation of surface brightness

$$\underbrace{I(\vec{\theta})}_{\text{image plane brightness}} = \underbrace{I_s(\vec{\beta})}_{\text{source plane brightness}} = I_s\left(\vec{\theta} - \underbrace{\vec{\alpha}(\vec{\theta})}_{\text{deflection}}\right)$$

- performed by bi-linear interpolation

Visualisation of the mock lensed image of the lightcone

Size: 1 square degree

Resolution: 0.1 arcsec

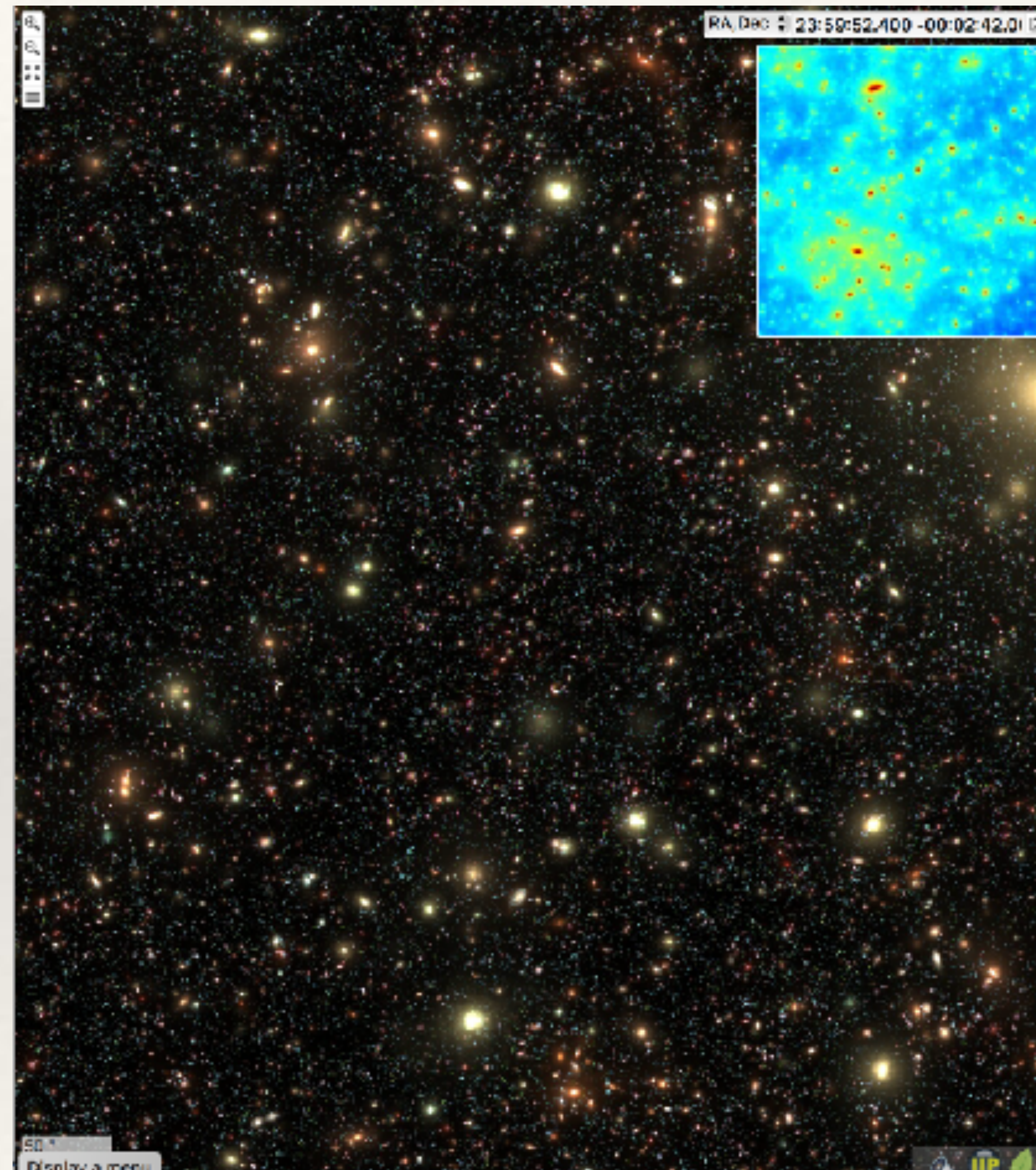
All the stars between z=0.05 and z ~ 7

The position of galaxies with

$$M_* > 1 \times 10^{10} M_\odot$$

are identified in the image

Critical lines for redshift source at zs = 1.2 and 3.5 are also computed



based on visiomatic (E. Bertin)

http://amalgam2.iap.fr/Horizon-AGN/show.html

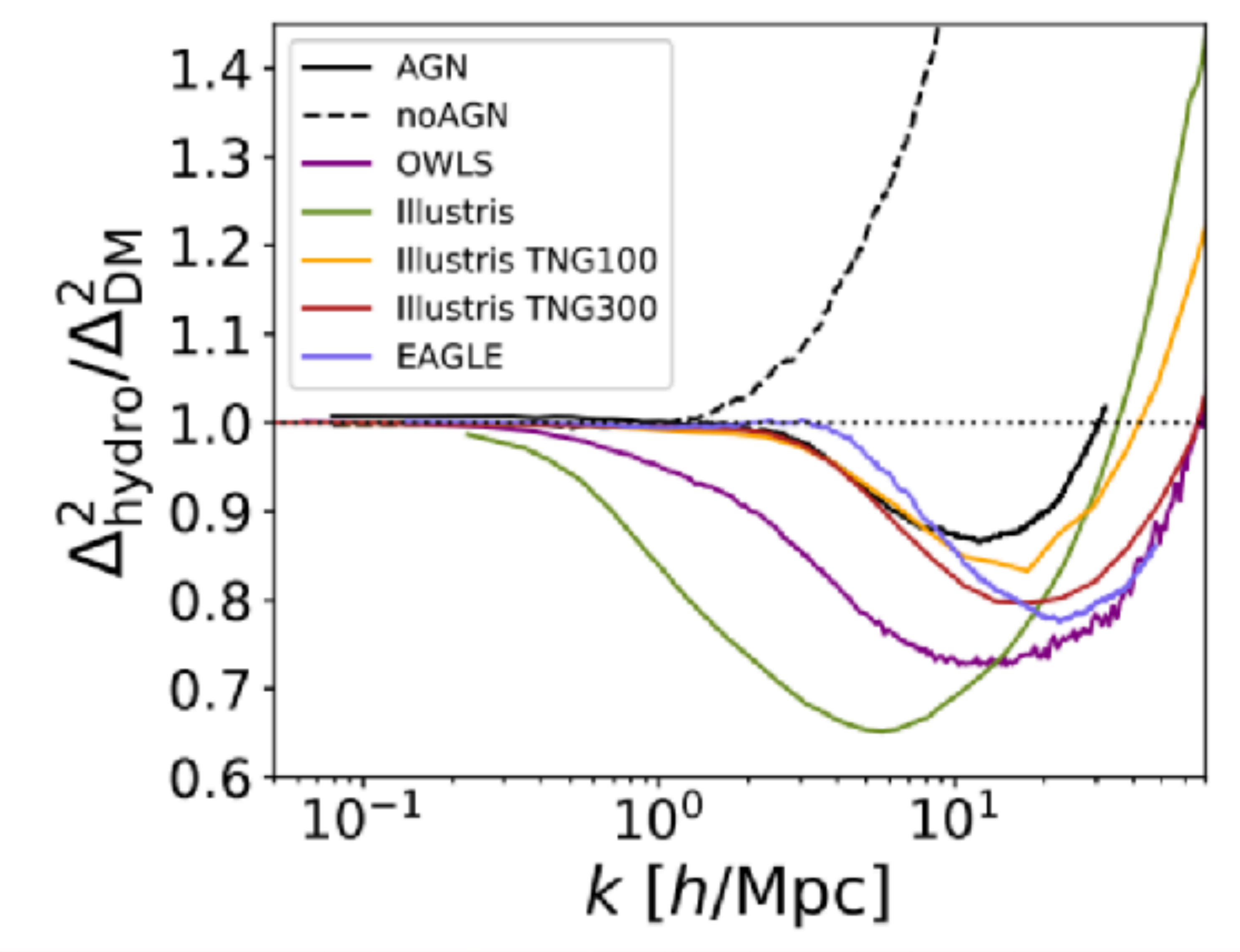
Conclusion & Perspectives

Future challenges..

- **Improve** statistical power in Hydrodynamical simulation (larger volume)

- Predict cosmological observables with **different subgrid models**

Understand the **degeneracies** between baryonic processes and cosmology



E. Chisari, et al 2018

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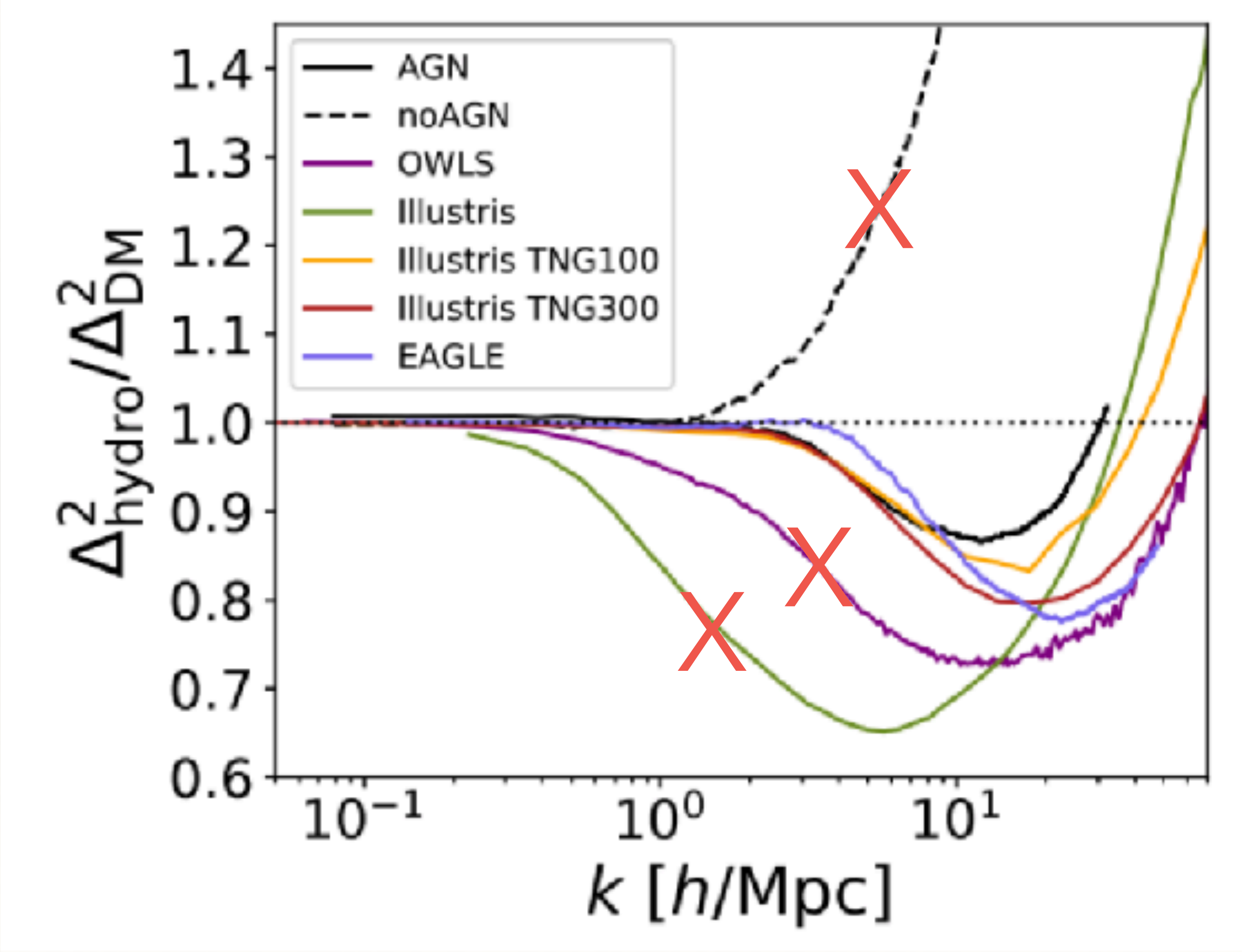


Elisa Chisari, et al 2018

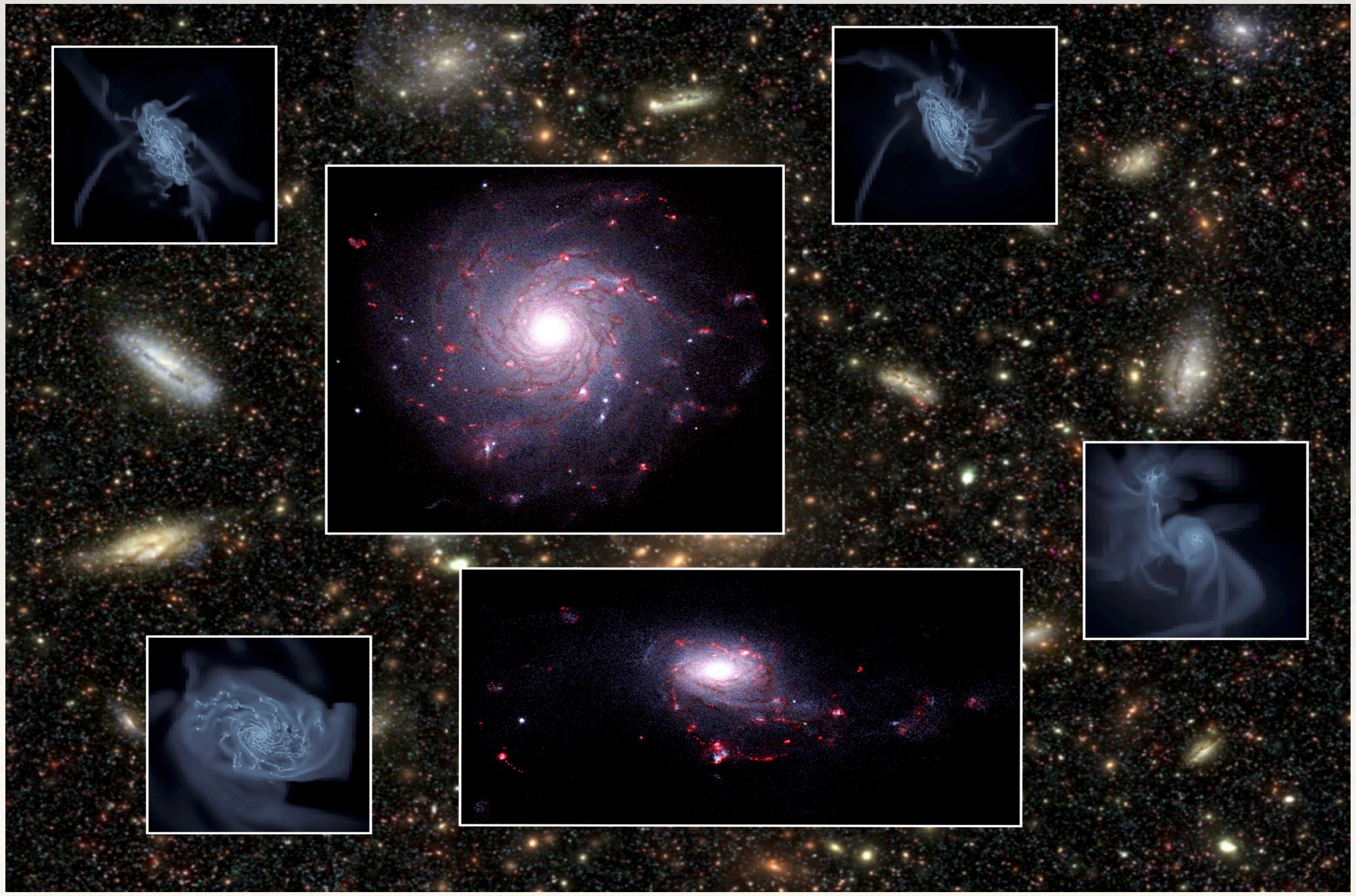
Conclusion & Perspectives

Future challenges..

- Improve power statistics in Hydrodynamical simulation:

- Predict cosmological observables with **different subgrid models**

- Test the validity of subgrid physics recipes - Resolve disc of galaxies



smaller scale lensing: for galaxy-galaxy lensing and the strong lensing regimes

New-Horizon
(20 Mpc zoom - resolution 40pc)