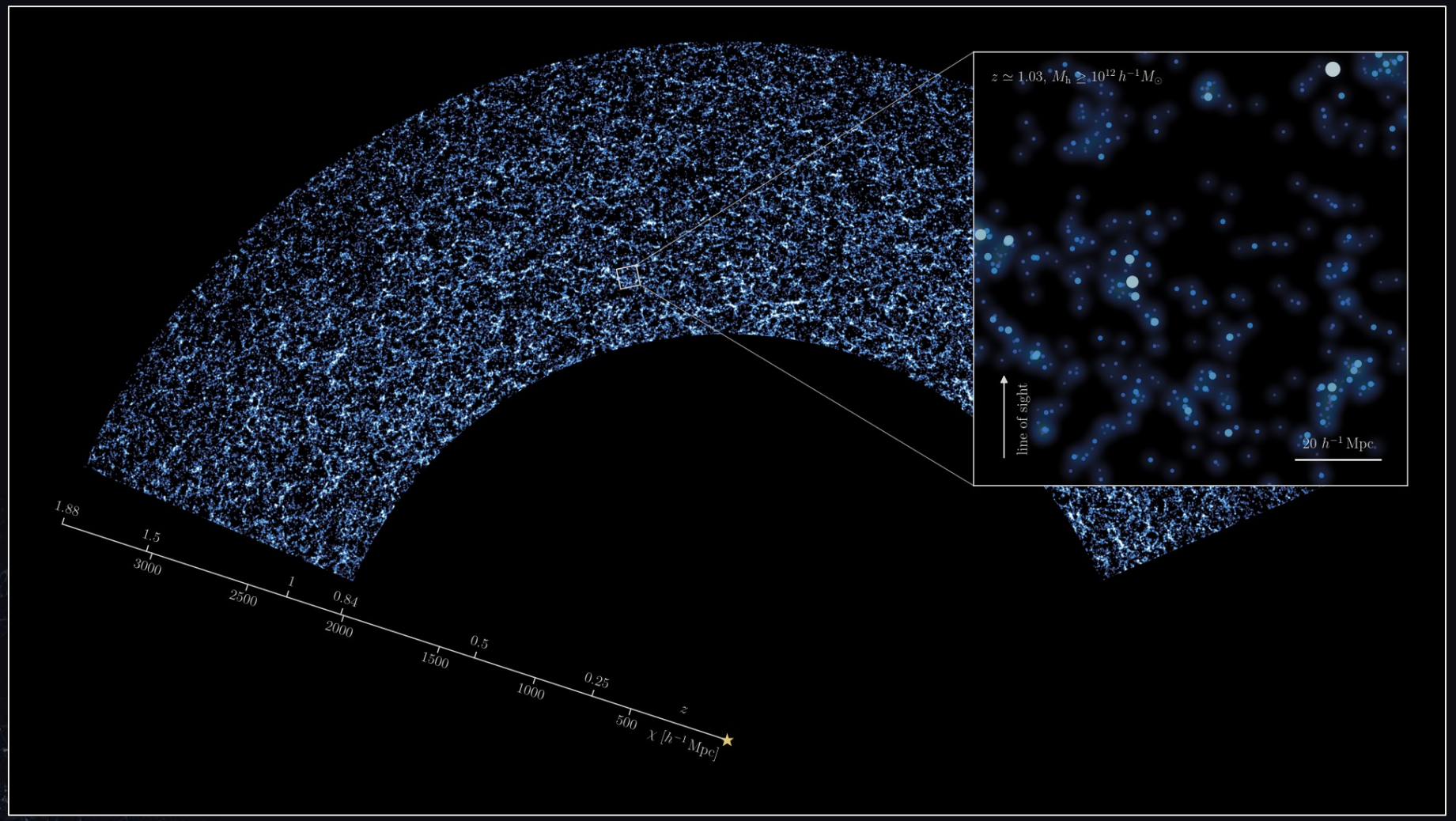


WG Dark Energy · PARIS · 2026

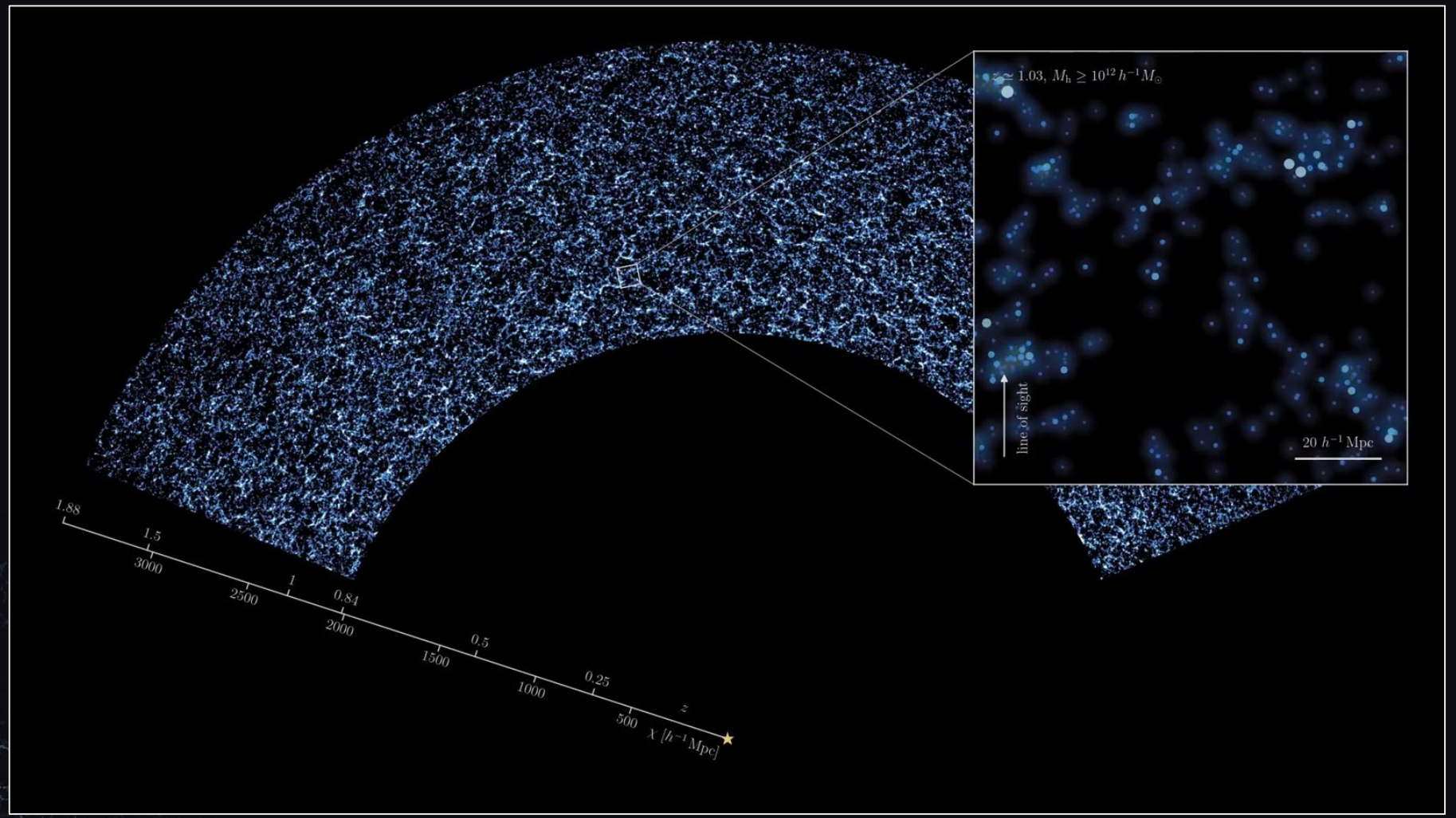
Simulating only what we observe

Fast, parallel N-body lightcones for cosmological surveys

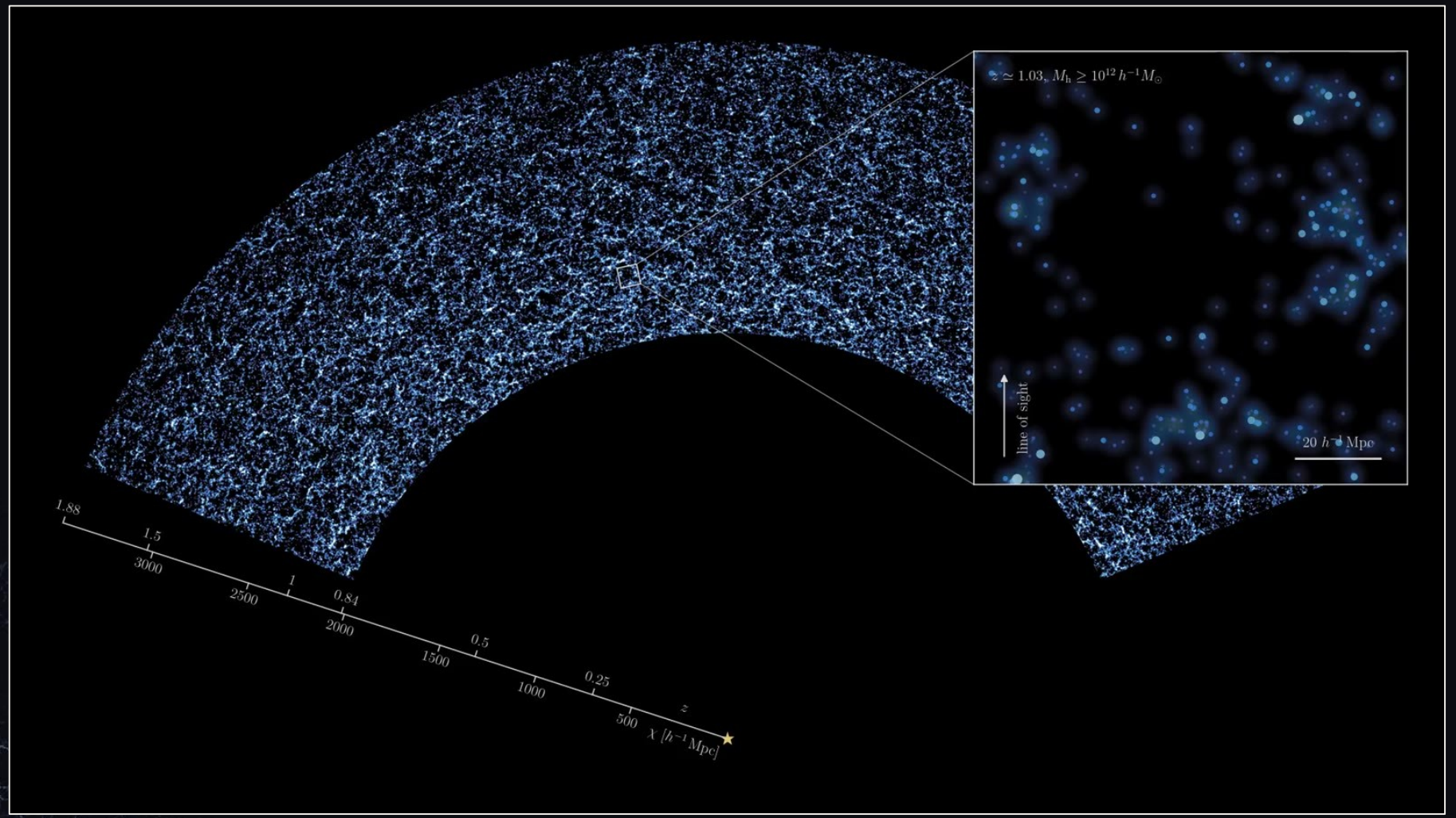
Mayeul Aubin
Institut d'Astrophysique de Paris · Aquila Consortium · Euclid Consortium
Supervised by Florent Leclercq & Guilhem Lavaux


$z \simeq 1.03,\ M_{\rm h} \geq 10^{12}\,h^{-1}M_\odot$
line of sight
$20\ h^{-1}\,\mathrm{Mpc}$
1.88
1.5
1
0.84
0.5
0.25
z
3000
2500
2000
1500
1000
500
$\chi\ [h^{-1}\mathrm{Mpc}]$

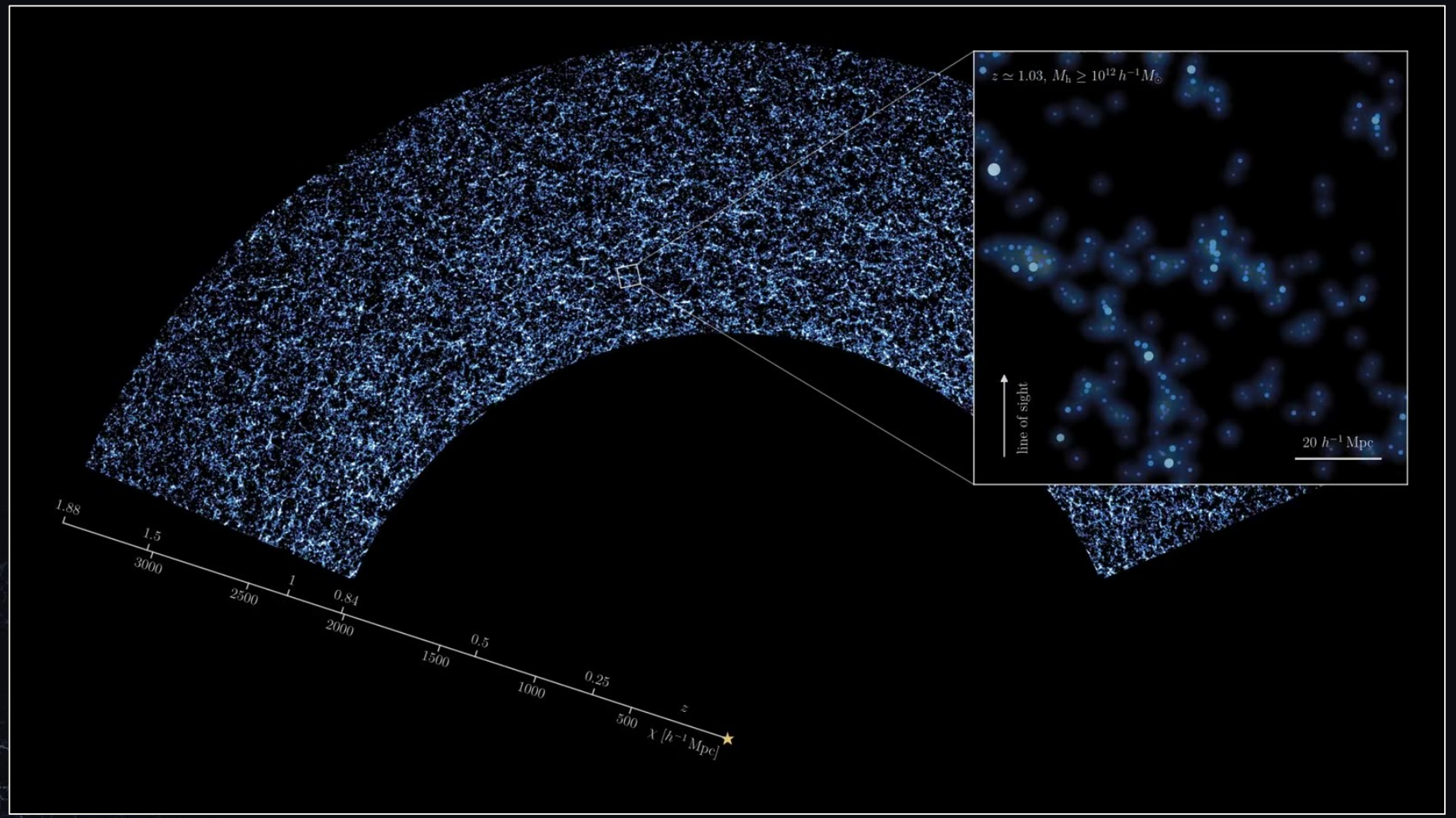
With sCOLA lightcones we produced 100 Euclid N-body simulations for 3 million CPU hours



With sCOLA lightcones we produced 100 Euclid N-body simulations for 3 million CPU hours



With sCOLA lightcones we produced 100 Euclid N-body simulations for 3 million CPU hours



$\times 8\,000$

cheaper than a standard N-body code

$\sim 1\%$

deviations from a standard N-body code

OUTLINE

Towards cheap and reliable cosmological simulations

I.

N-body simulations

Precise simulations for cosmological surveys

II.

sCOLA lightcones

Fast large N-body simulations

III.

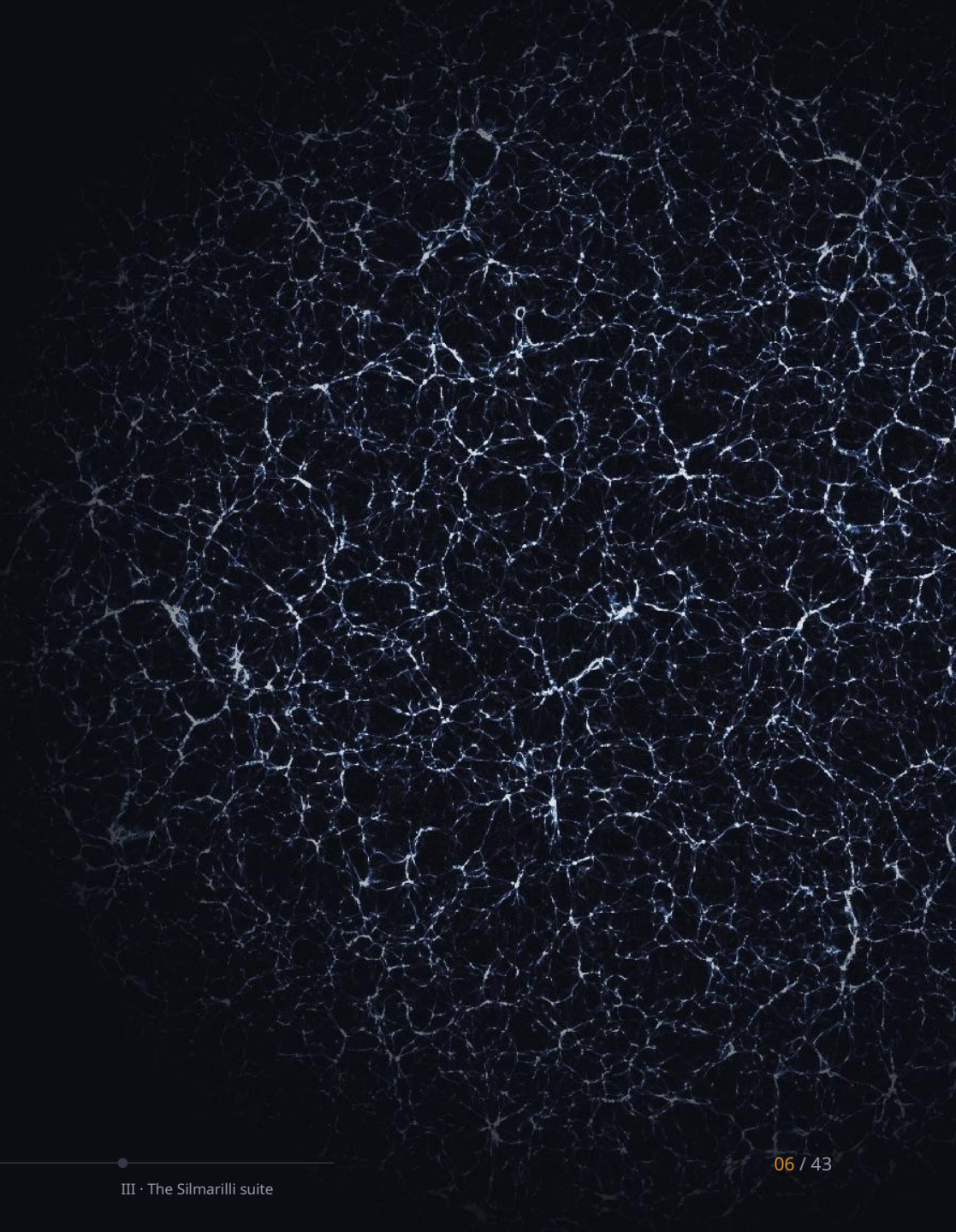
The Silmarilli suite

Euclid-scale sCOLA lightcones

I.

N-body simulations

Why are N-body simulations both essential and expensive?



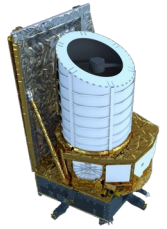
Looking far is looking back in time

Supernovae

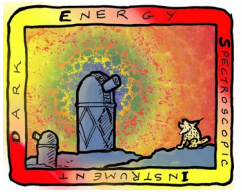




CMB



Galaxy positions (clustering)
Galaxy shapes (weak lensing)







Planck Collaboration et al. (2020) · A&A 641, A6 · arXiv:1807.06209

Large cosmological surveys map the sly

Euclid

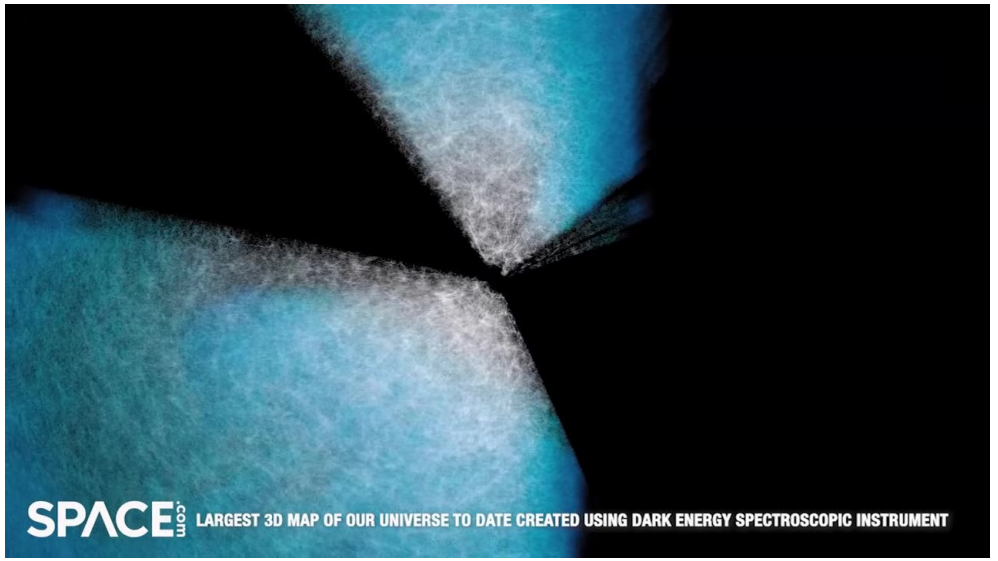
0.84 < z < 1.88 for the clustering, 14.5 K deg^2 wide survey, ~20 M galaxies



Rendering of our Eä simulation dark matter halos restricted to a plausible Euclid mask.

DESI

0 < z < 4, ~47 M galaxies and quasars



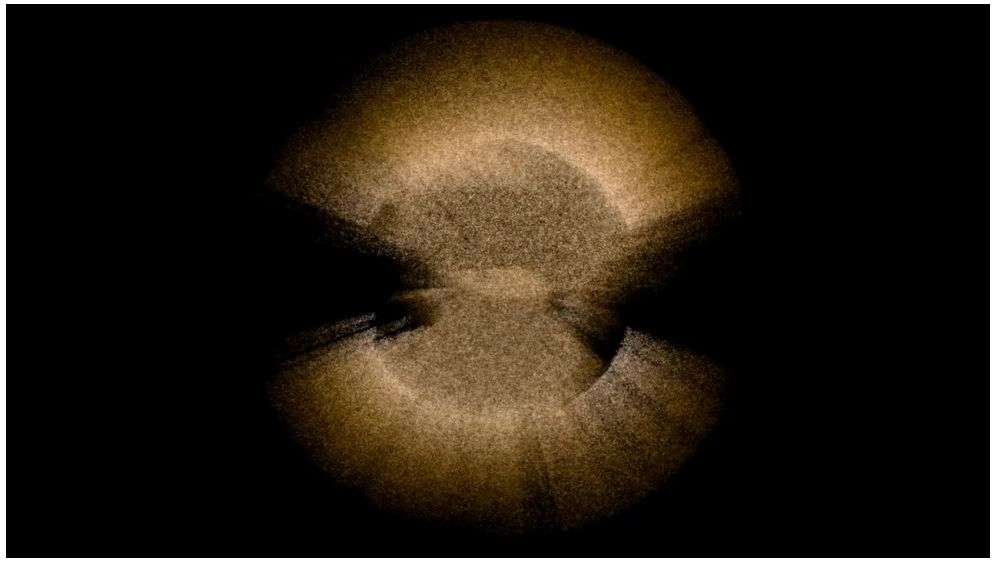
Rendering of DESI galaxies done by space.com

Euclid Collaboration et al. (2022) · A&A 662, A112 · doi:10.1051/0004-6361/202141938
DESI Collaboration et al. (2023) · preprint · arXiv:2306.06307

Large cosmological surveys map the sly

Euclid

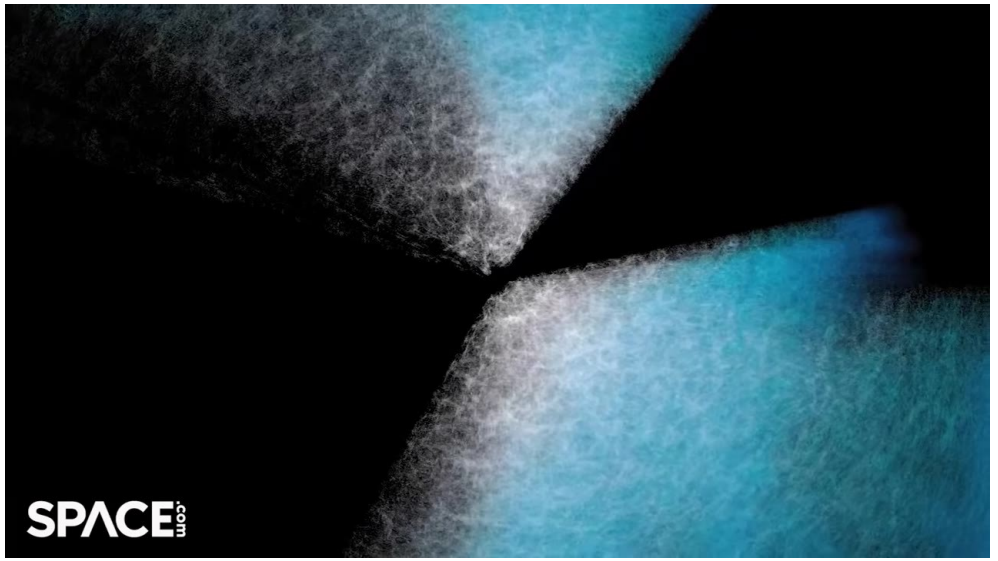
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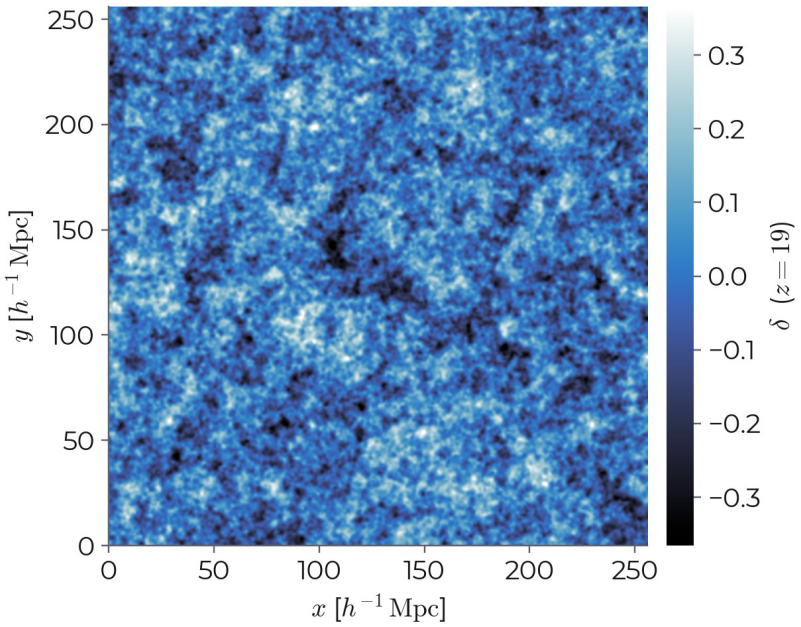


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Euclid Collaboration et al. (2022) · A&A 662, A112 · doi:10.1051/0004-6361/202141938
DESI Collaboration et al. (2023) · preprint · arXiv:2306.06307

Simulations try to reproduce what we observe

Cosmological parameters



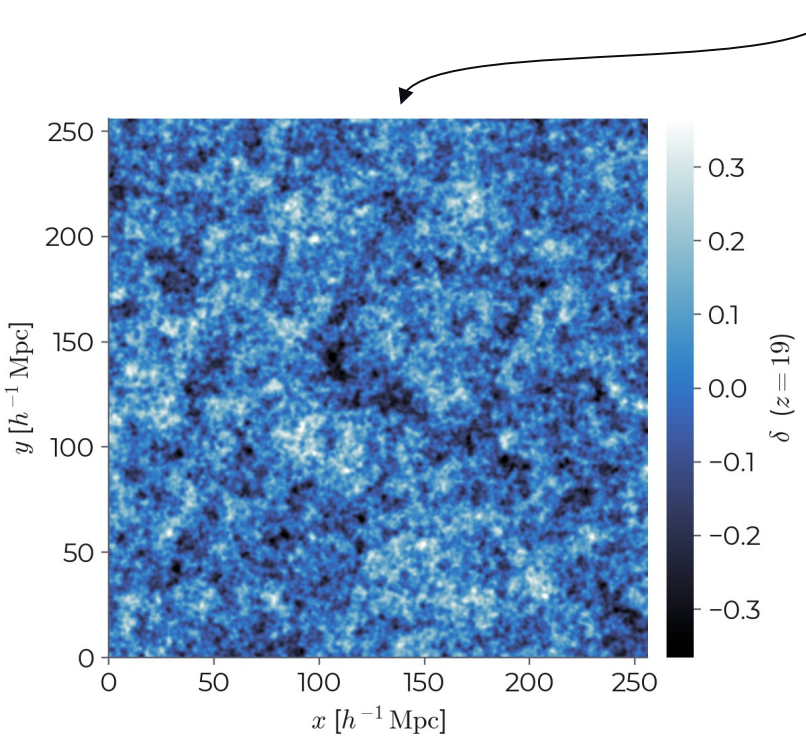
Initial conditions field

Gravity model

Angulo R. E. & Hahn O. (2022) · Living Rev Comput Astrophys 8, 1 · arXiv:2112.05165

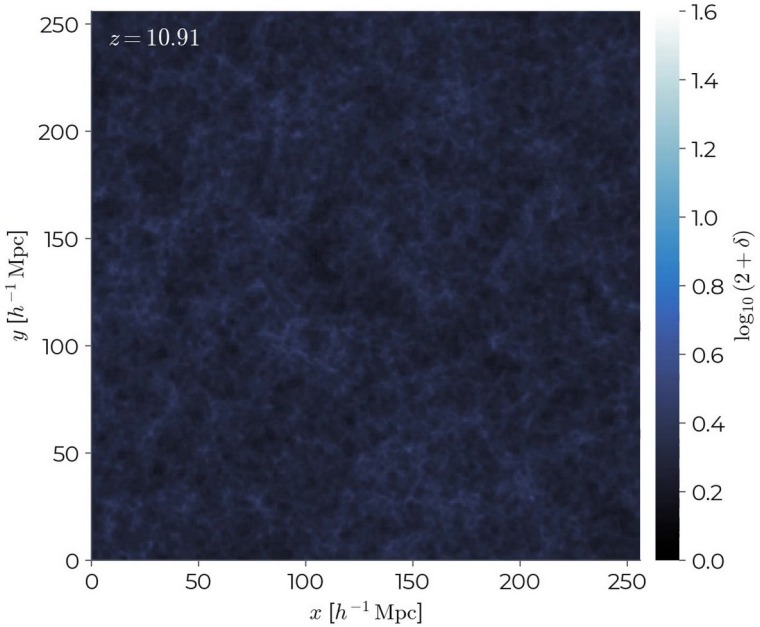
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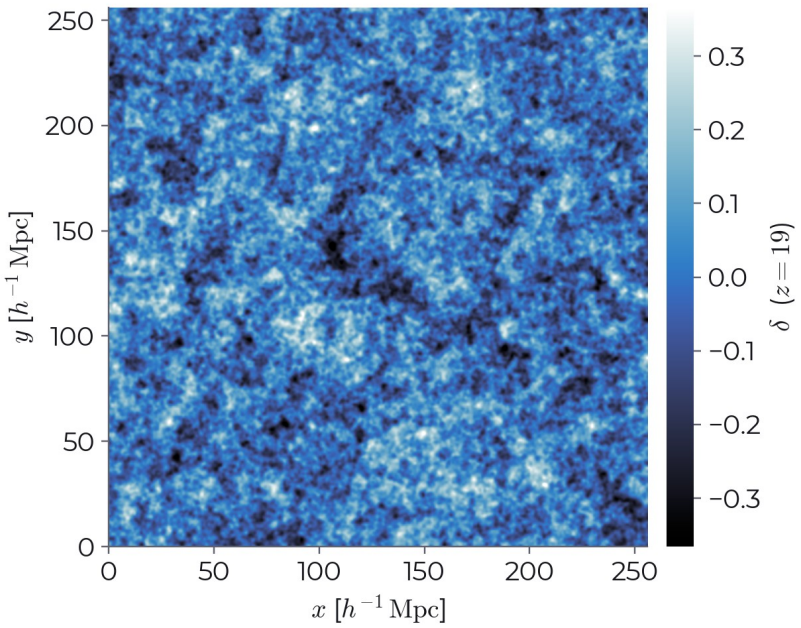


Dark matter final field

Angulo R. E. & Hahn O. (2022) · Living Rev Comput Astrophys 8, 1 · arXiv:2112.05165

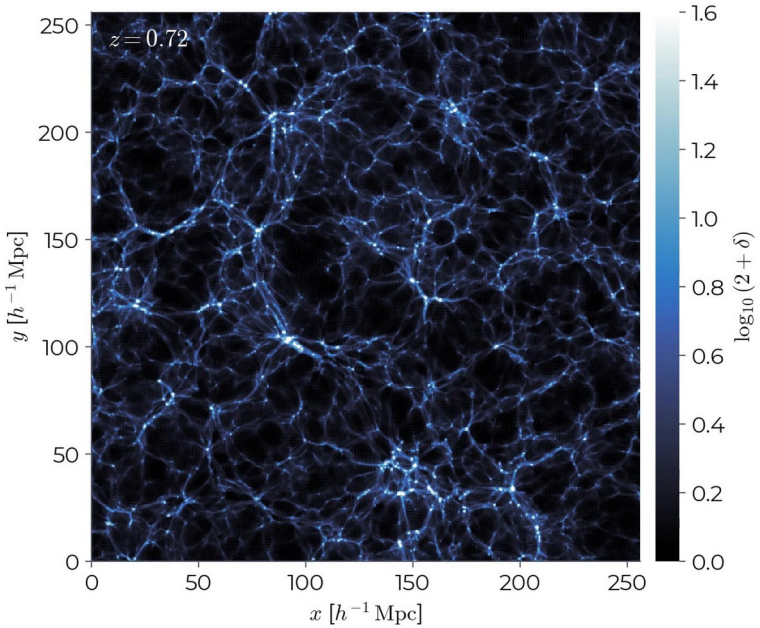
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Cosmological parameters



Initial conditions field

Gravity model

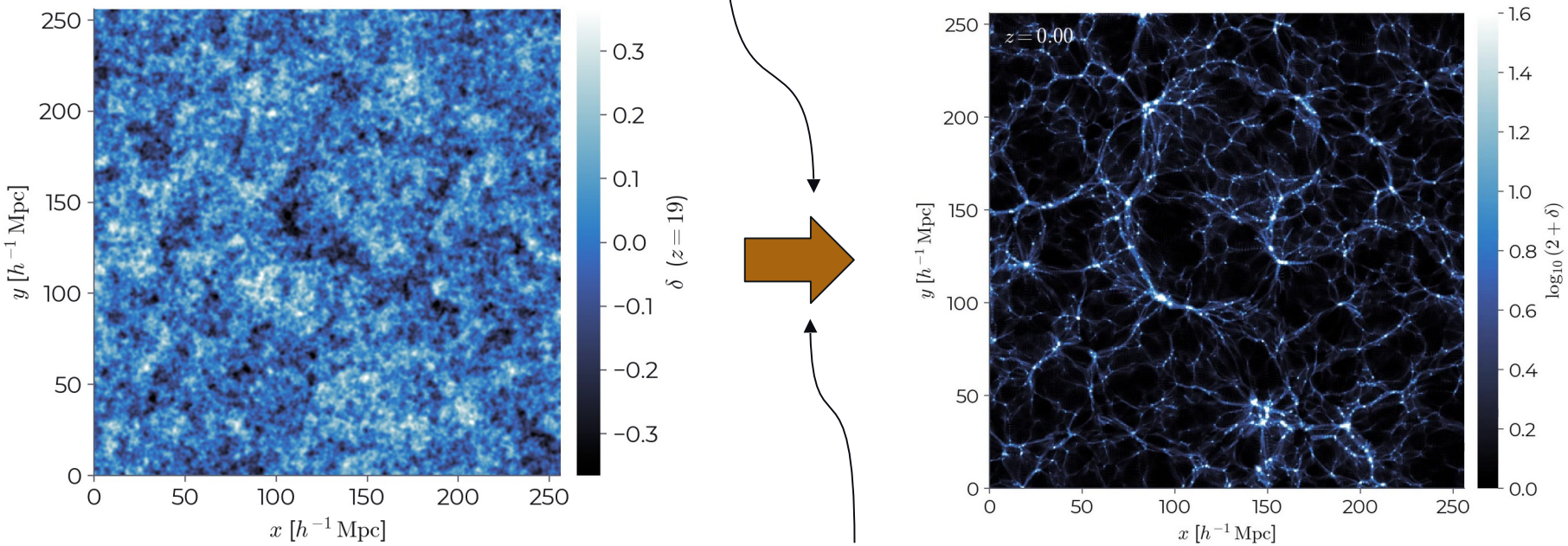


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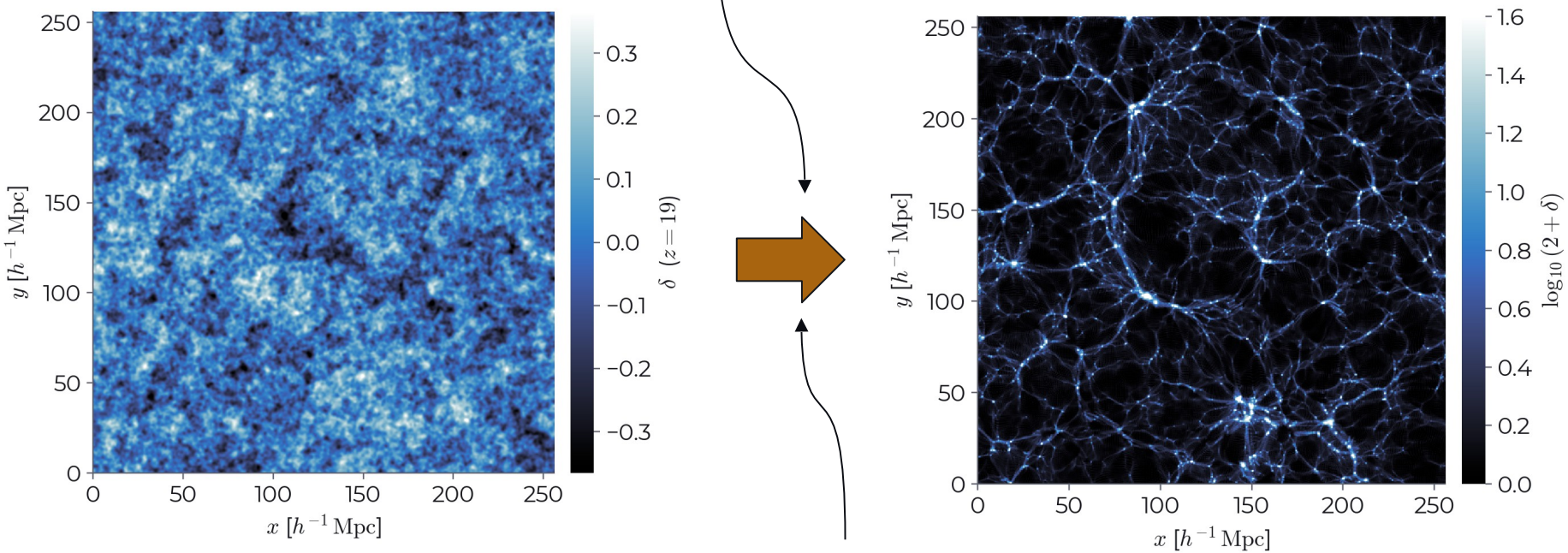
Gravity model

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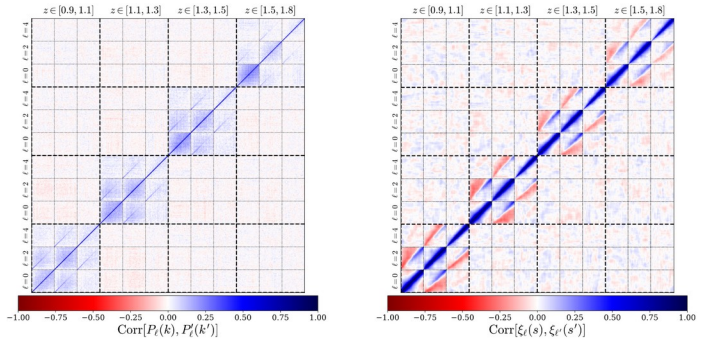
Gravity model

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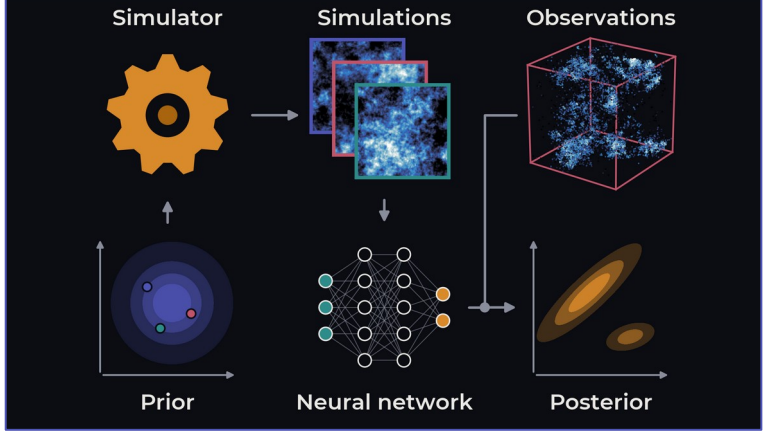
Angulo R. E. & Hahn O. (2022) · Living Rev Comput Astrophys 8, 1 · arXiv:2112.05165

We need suites of N-body simulations to compare with reality

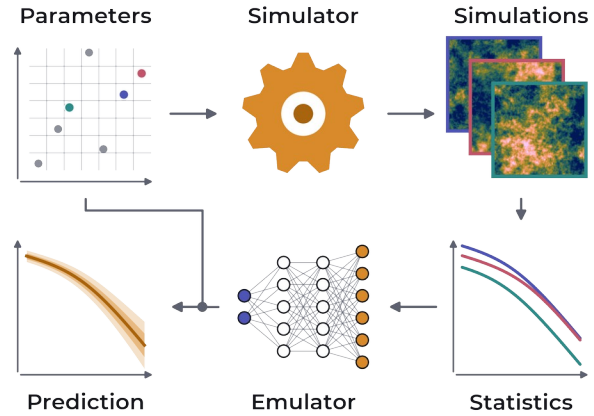
Covariance estimation



Simulation Based Inference



Emulator training



Euclid Collaboration et al. (2025) · A&A 704, A306 · doi:10.1051/0004-6361/202556459
Forero-Sánchez D. et al. (2025) · JCAP 2025, 055 · arXiv:2411.12027
Hahn C. et al. (2023) · preprint · arXiv:2310.15246
Aricò G. et al. (2021) · MNRAS 506, 4070 · arXiv:2011.15018

We need suites of N-body simulations to compare with reality



Example: Quijote suite of N-body simulations

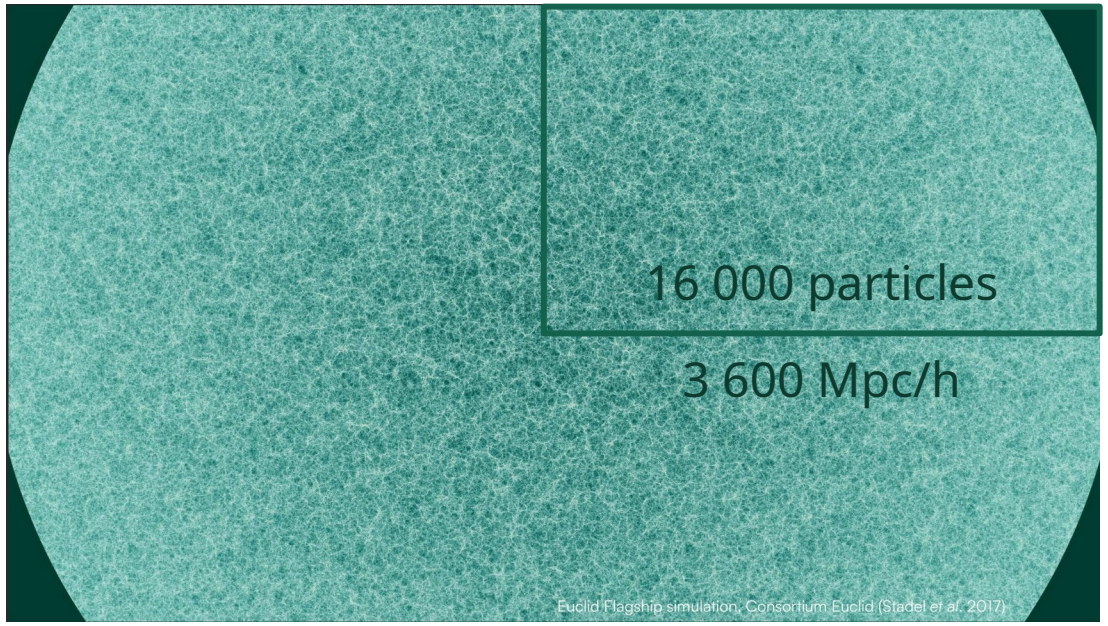
82 000 Gadget N-body simulations at low resolution (6.4 10^{12} solar masses) and medium size box (1 Gpc/h), for a cost of 35 million CPU hours. Total of 8.5 10^{12} particles over all simulations.

Can we do better with less budget?

Villaescusa-Navarro F. et al. (2020) · ApJS 250, 2 · arXiv:1909.05273
Villaescusa-Navarro F. et al. (2021) · ApJ 915, 71 · doi:10.3847/1538-4357/abf7ba
Genel S. et al. (2026) · preprint · arXiv:2606.10038
Maksimova N. A. et al. (2021) · MNRAS 508, 4017 · arXiv:2110.11398
Kacprzak T. et al. (2023) · JCAP 2023, 050 · arXiv:2209.04662
Bayer A. E. et al. (2025) · JCAP 2025, 016 · arXiv:2407.17462
Euclid Collaboration et al. (2025) · A&A 704, A306 · doi:10.1051/0004-6361/202556459

But N-body simulations are prohibitively expensive

Example: the Euclid Flagship Simulation



PROPERTY	EUCLID FLAGSHIP
Box size	3 600 Mpc/h
Particles	$(16\,000)^3 = 4 \times 10^{12}$
Mass resolution	$10^9\ M_\odot$
Estimated CPU cost	68 M CPUh
Estimated RAM cost	240 TB
TGCC estimated cost	400 K €
Estimated carbon footprint	75 tCO2e / 10 car trips around the earth

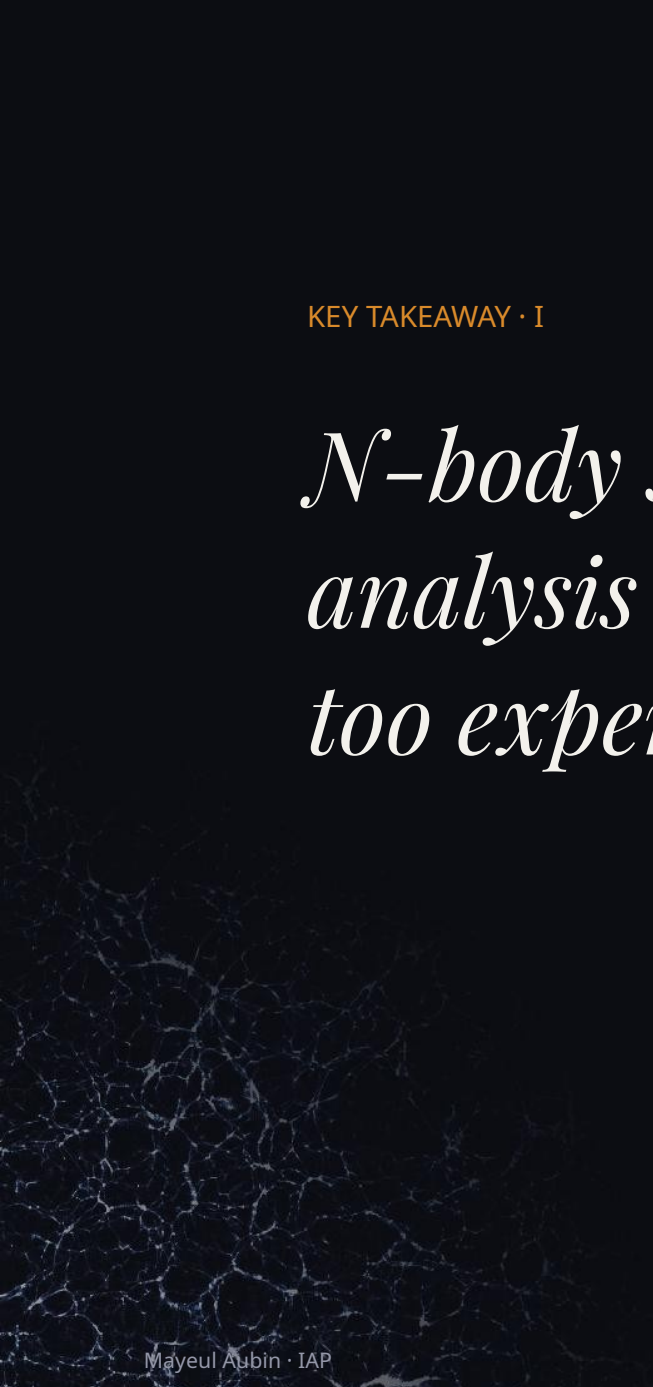
Euclid Collaboration et al. (2025) · A&A 697, A5 · arXiv:2405.13495
https://www.edari.fr/documentation/index.php/Documentation_compl%C3%A8te
https://impactco2.fr/outils/comparateur

Are they anymore?

10 times more particles for 10 times less budget than the Quijote suite

KEY TAKEAWAY · I

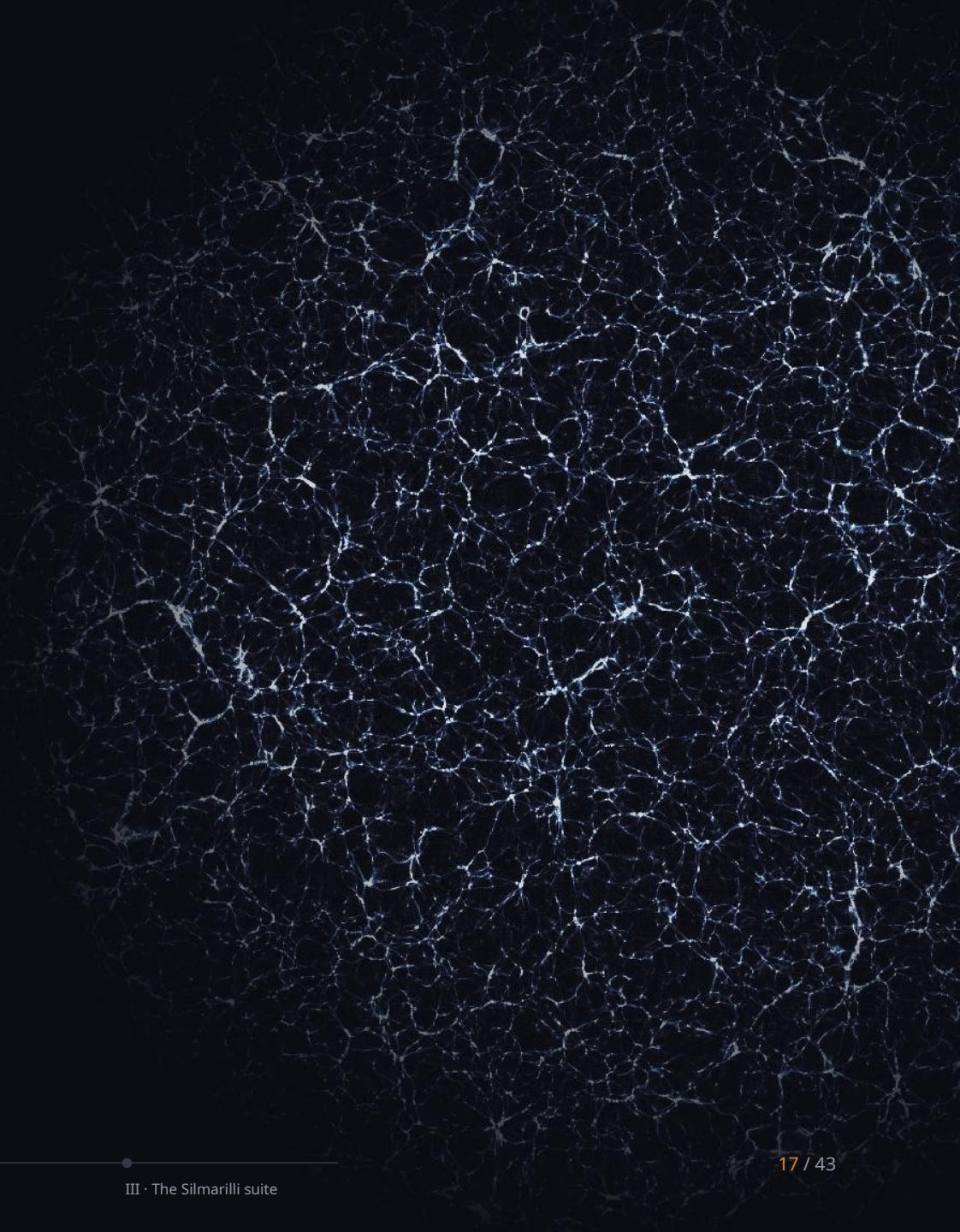
N-body simulations are necessary for the analysis of cosmological surveys, but they are too expensive...



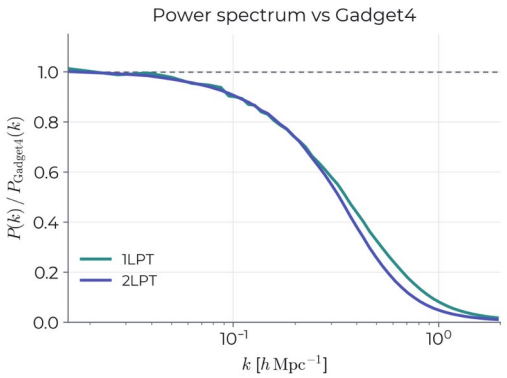
II.

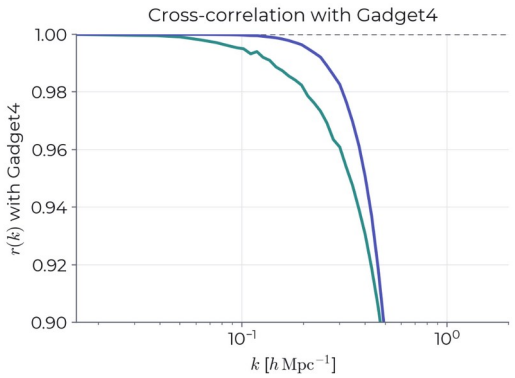
sCOLA lightcones

Divide the volume, conquer the cost

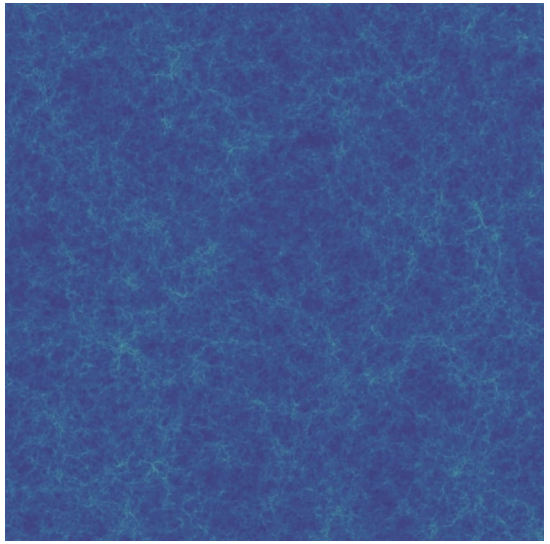


Is Lagrangian Perturbation Theory (LPT) good enough?

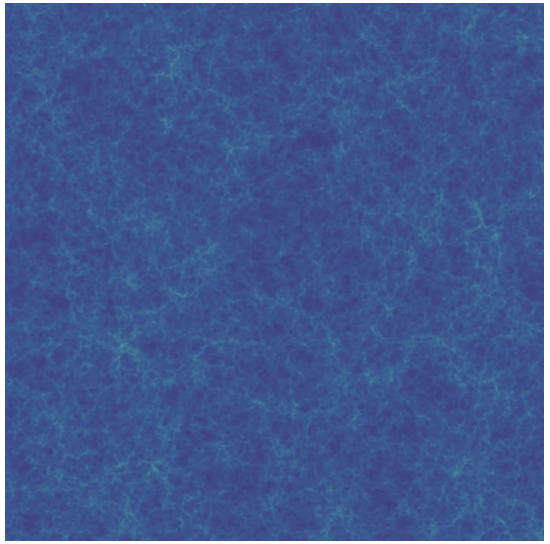




LPT

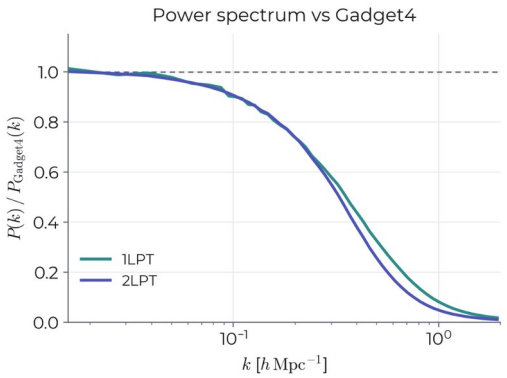


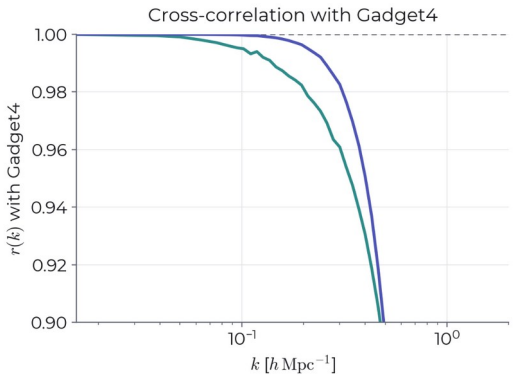
N-body



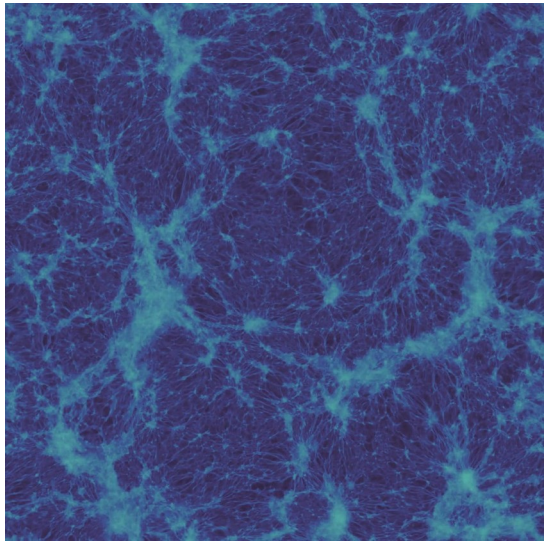
courtesy of F. Leclercq

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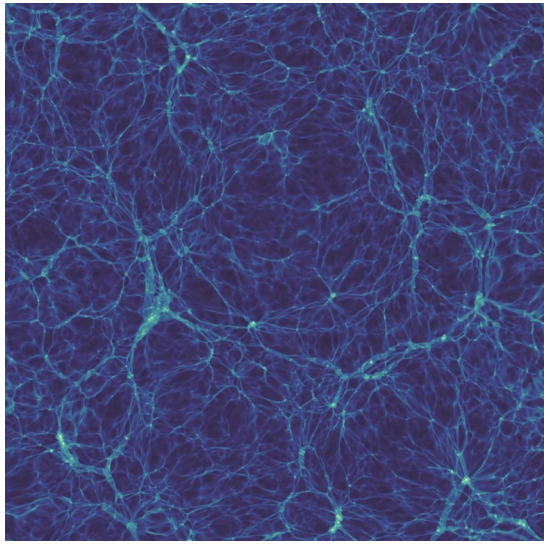




LPT

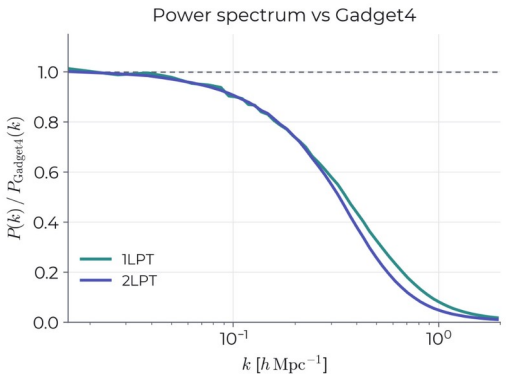


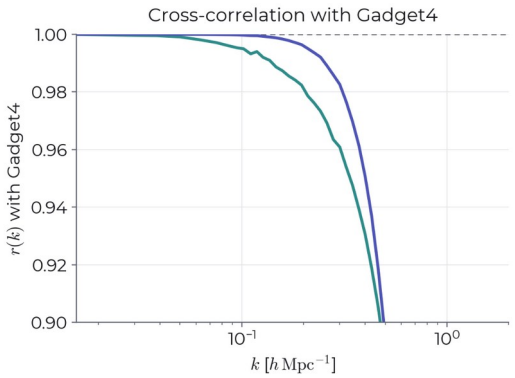
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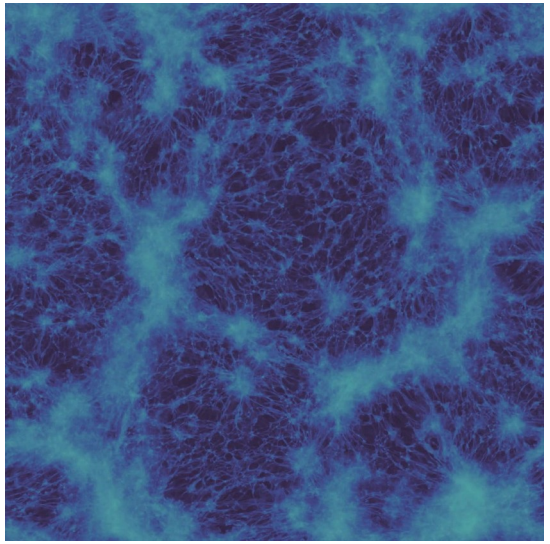
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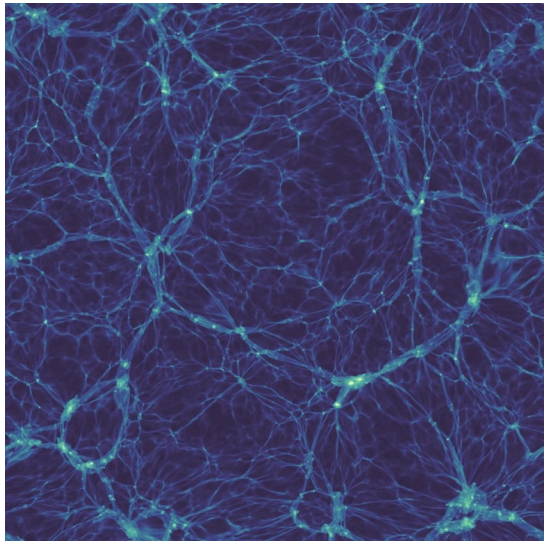




LPT

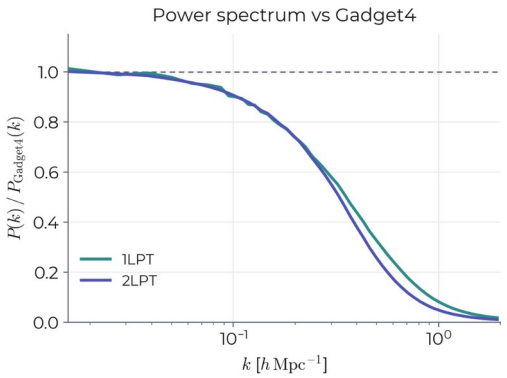


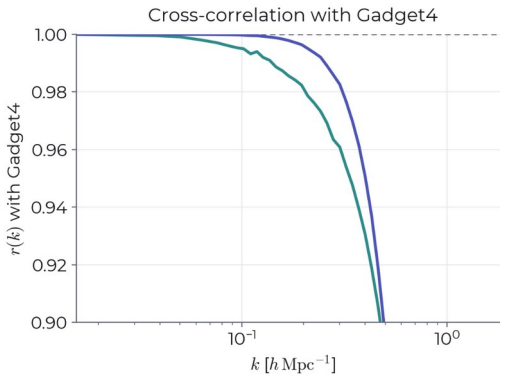
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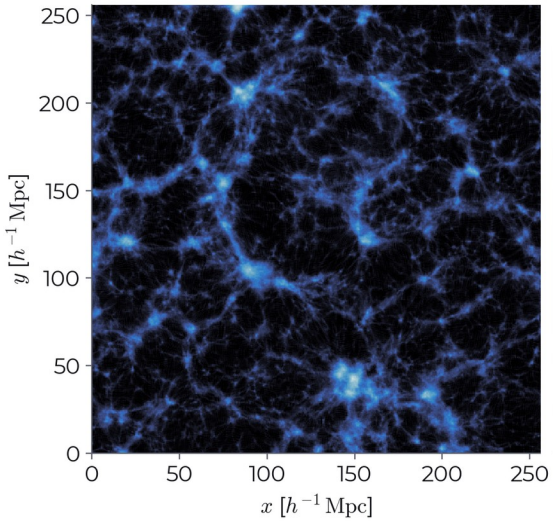
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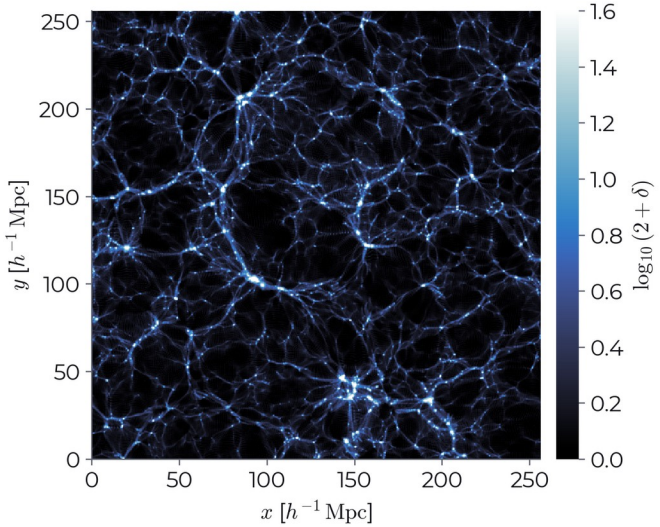




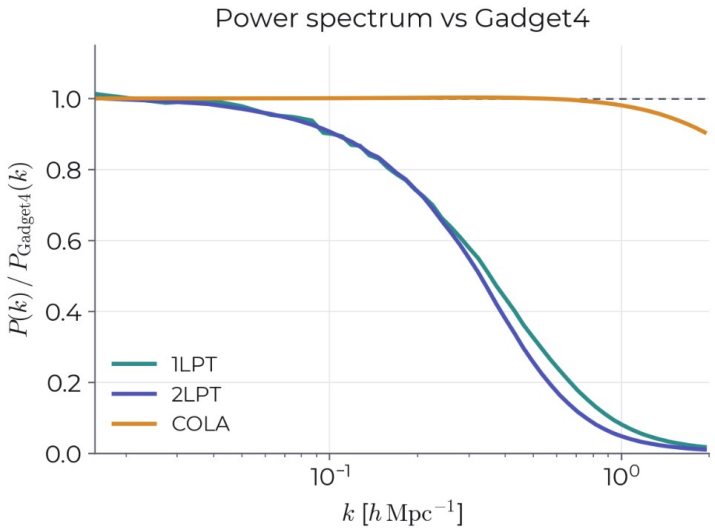
LPT

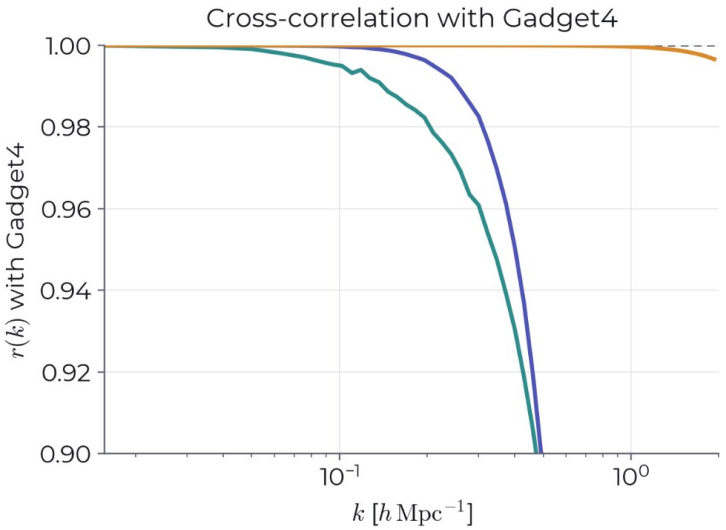


N-body

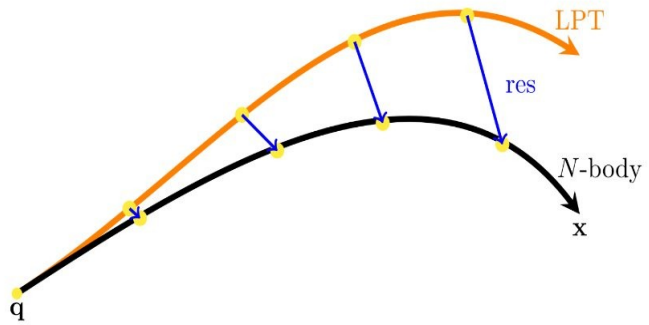


Maybe we can build an N-body solver upon 2LPT?





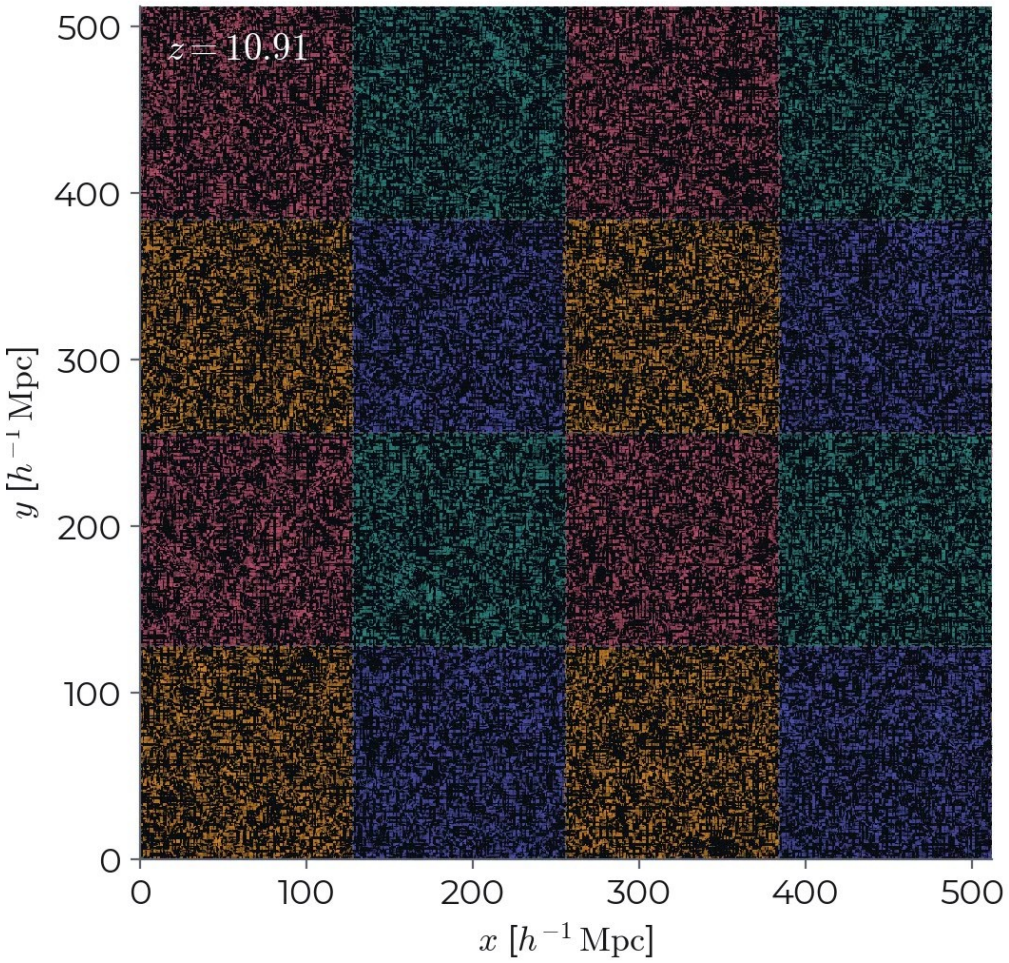
COmoving Lagrangian Acceleration
We solve the N-body equations of motions in the reference frame of 2LPT



We leverage the accuracy of 2LPT in time, but not yet in space

Tassev S. et al. (2013) · JCAP 2013, 036 · arXiv:1301.0322
Leclercq F. et al. (2015) · JCAP 2015, 015 · arXiv:1502.02690
Izard A. et al. (2016) · MNRAS 459, 2327 · arXiv:1509.04685
Koda J. et al. (2016) · MNRAS 459, 2118 · arXiv:1507.05329
Howlett C. et al. (2015) · preprint · arXiv:1506.03737

2LPT provides a stepladder in time and in space



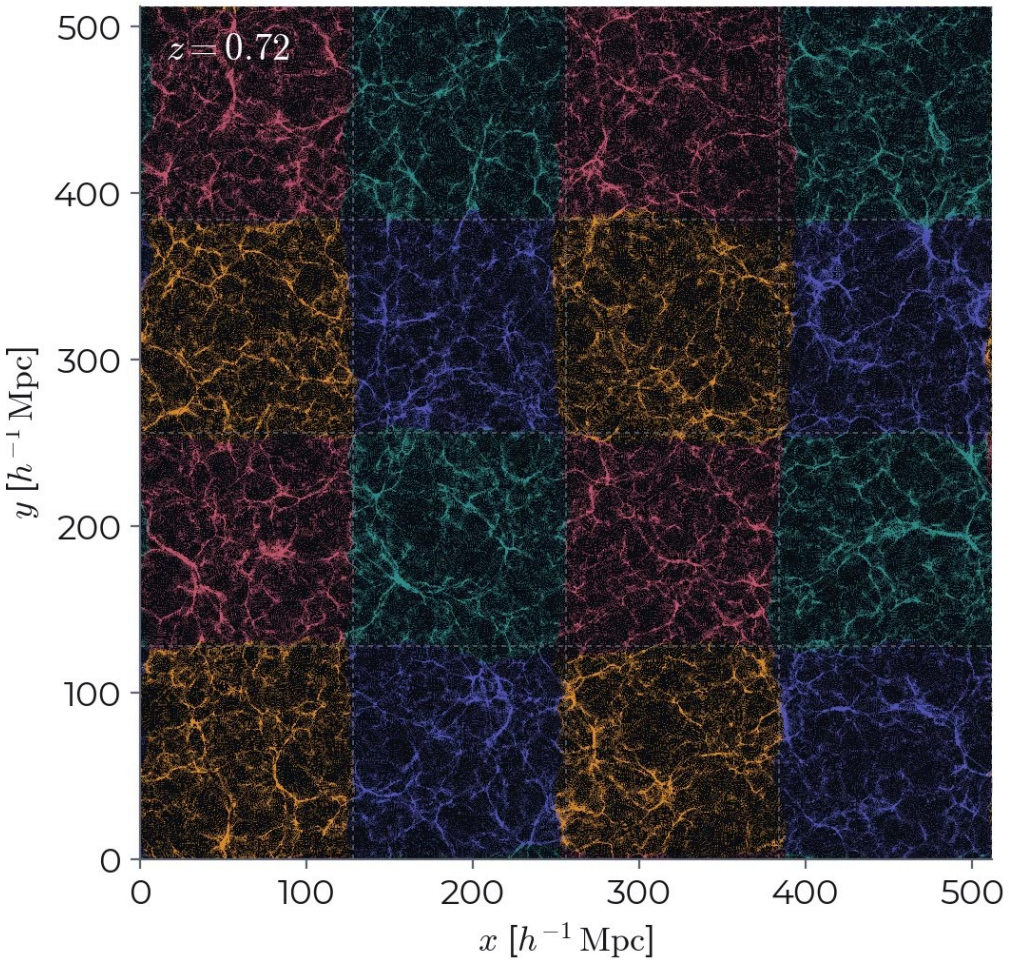
sCOLA splits the volume into independent tiles
Each tile, and a buffer around it, is evolved independently: we get a perfectly parallel N-body solver

4 CPUs and 6GB of RAM per tile
It can be more or less depending on the resolution and target accuracy

No communications between tiles!
But an oversimulation factor:

$$r \equiv \left(1 + 2\frac{L^{\mathrm{buffer}}}{L^{\mathrm{tile}}}\right)^3$$

2LPT provides a stepladder in time and in space



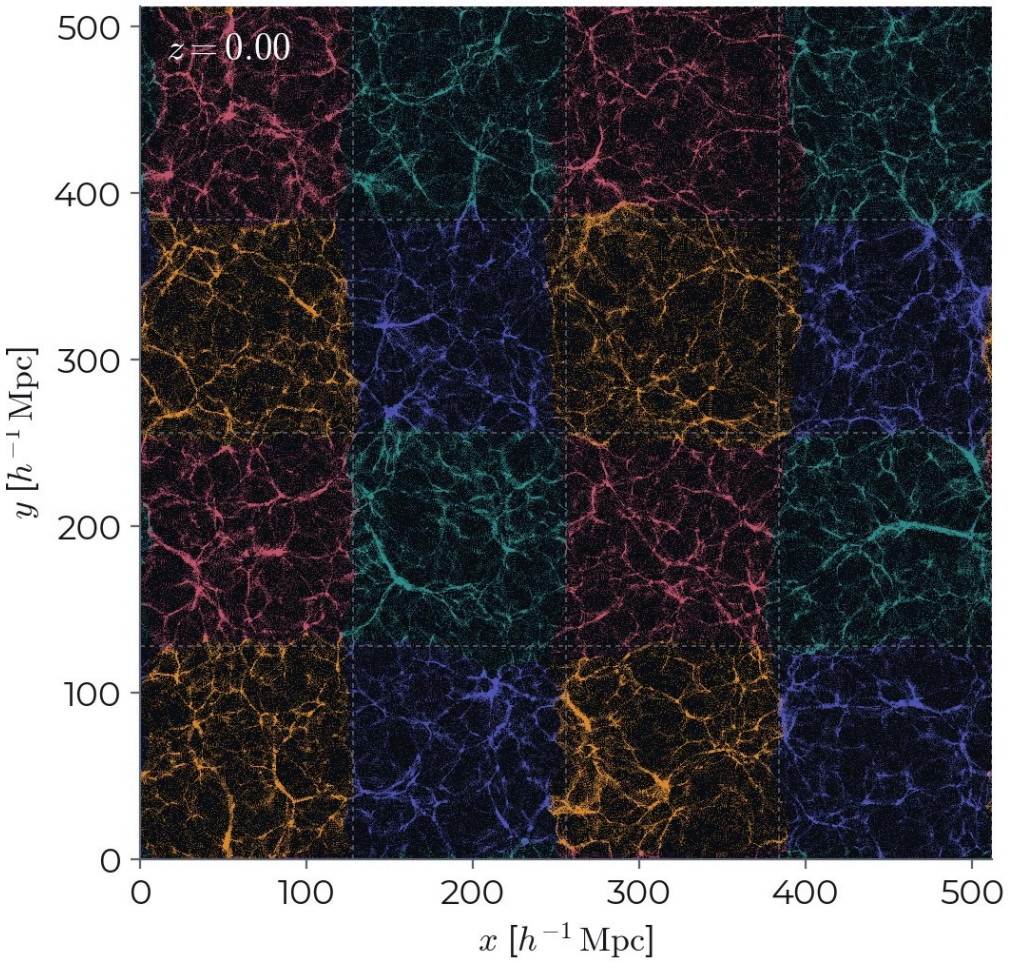
sCOLA splits the volume into independent tiles
Each tile, and a buffer around it, is evolved independently: we get a perfectly parallel N-body solver

4 CPUs and 6GB of RAM per tile
It can be more or less depending on the resolution and target accuracy

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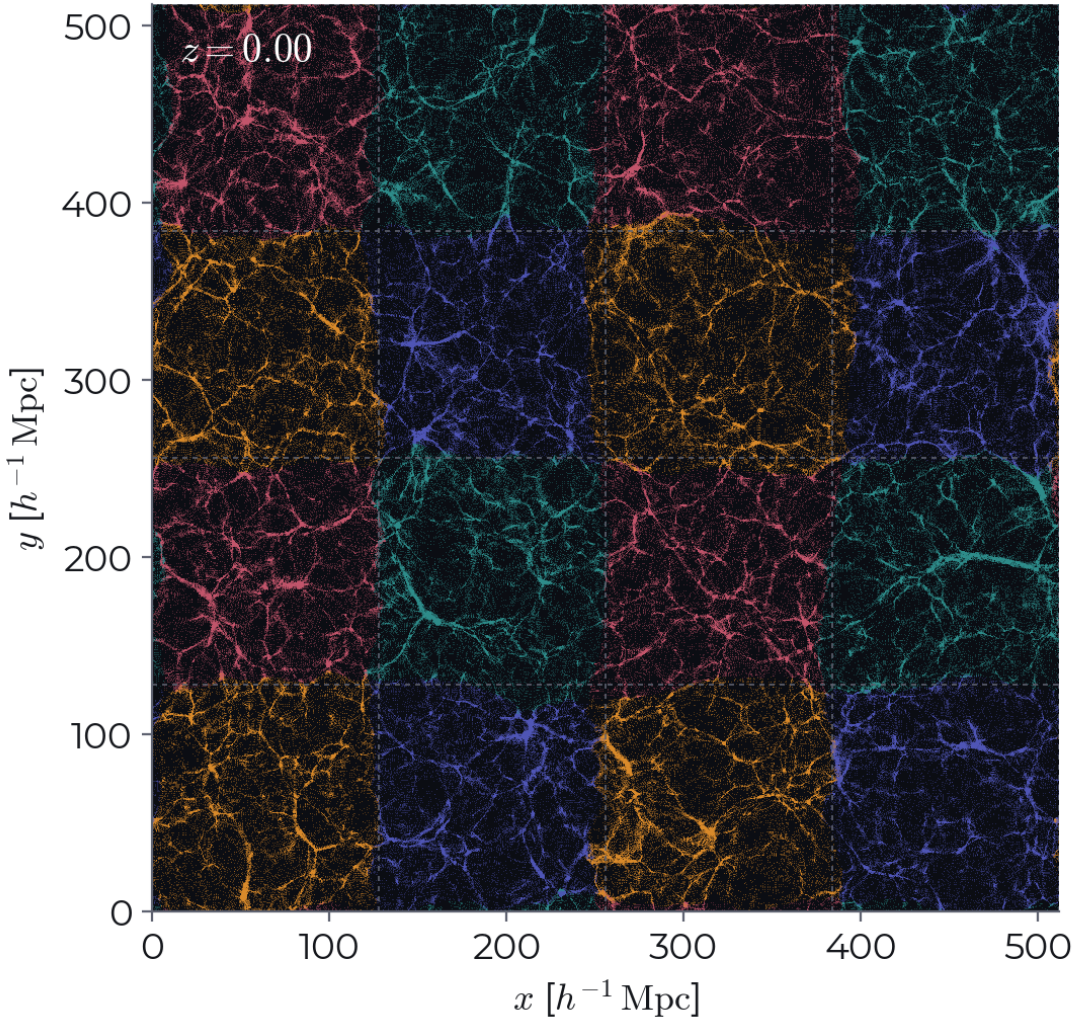
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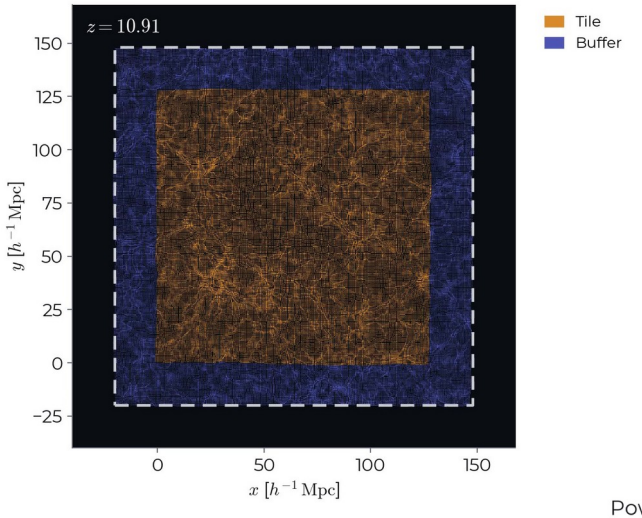
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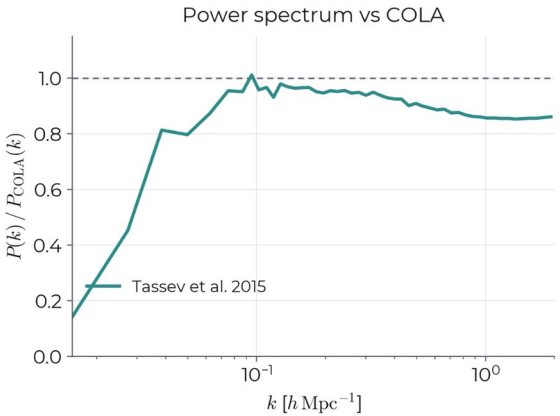
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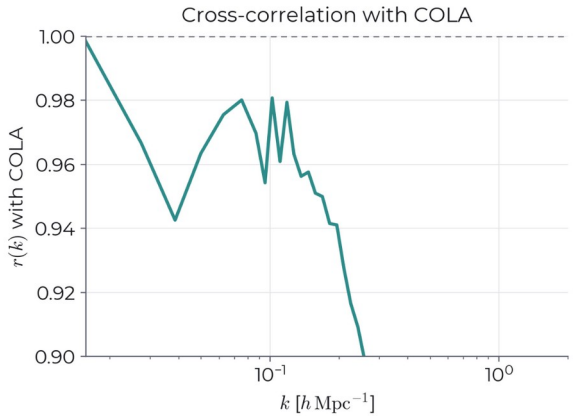
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sCOLA now converges well to COLA

Tassev et al. 2015



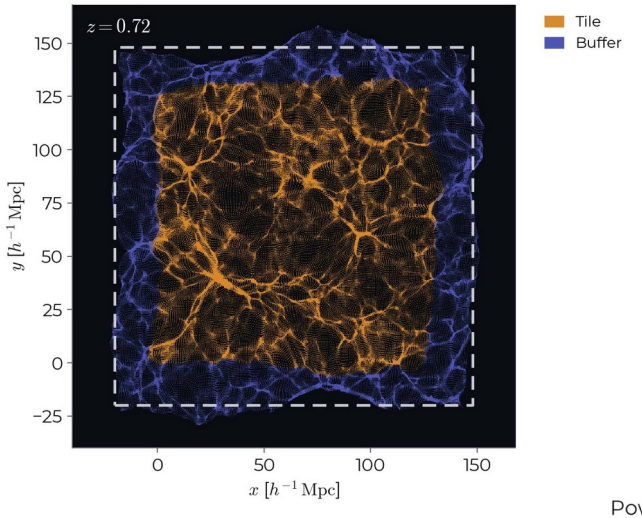


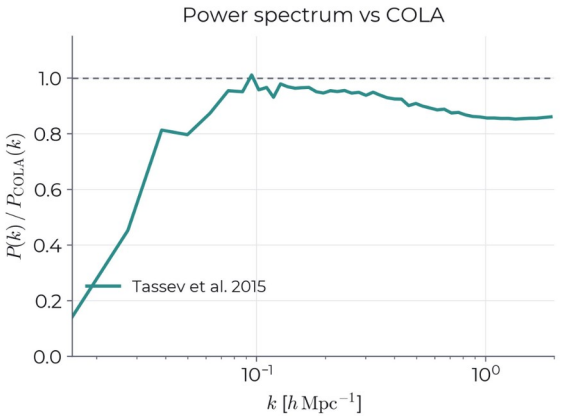


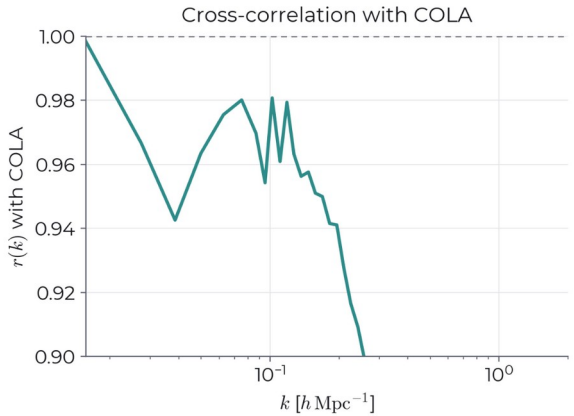
Tassev S. et al. (2015) · preprint · arXiv:1502.0775
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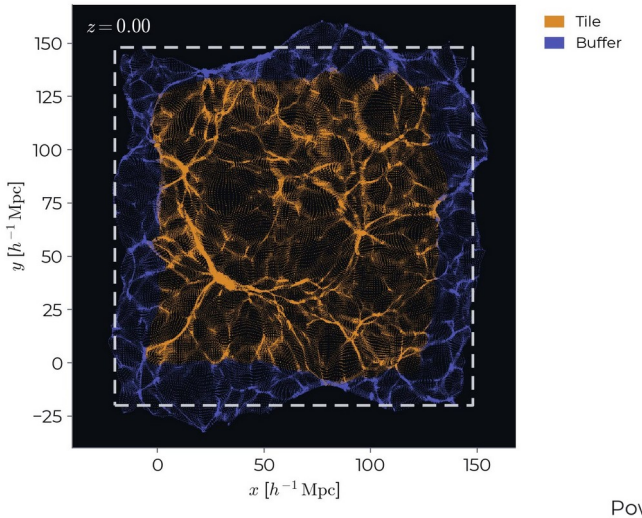


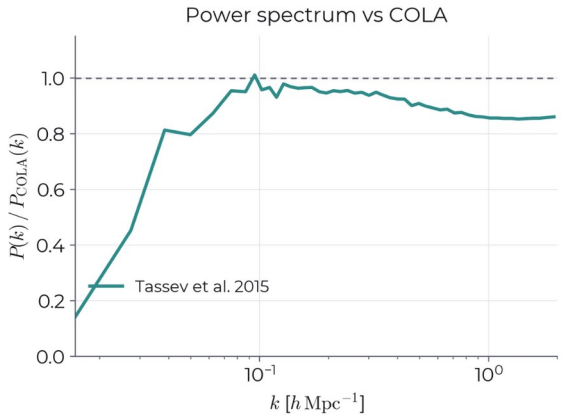


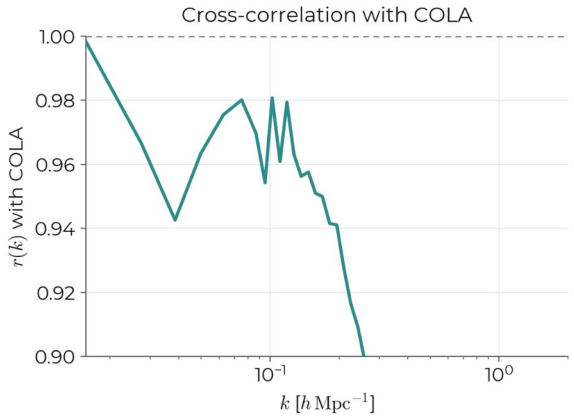
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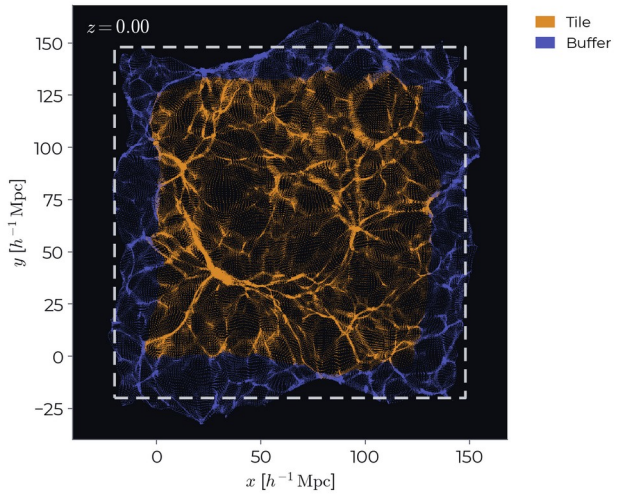




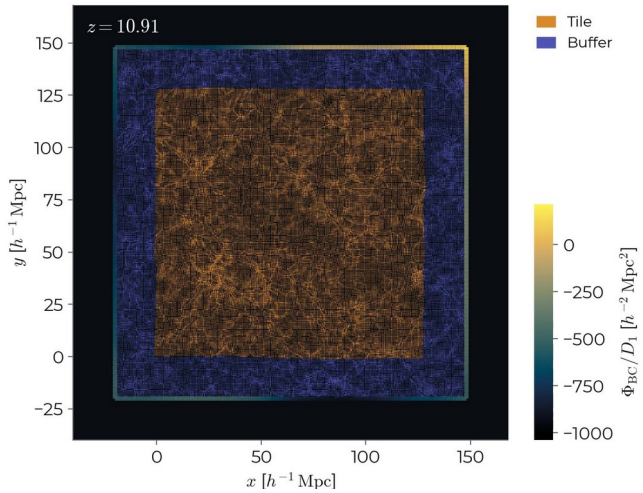
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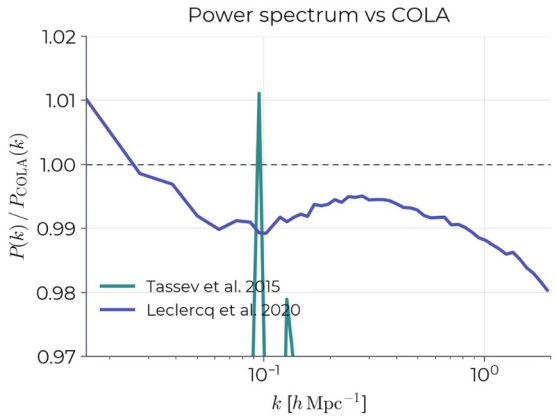
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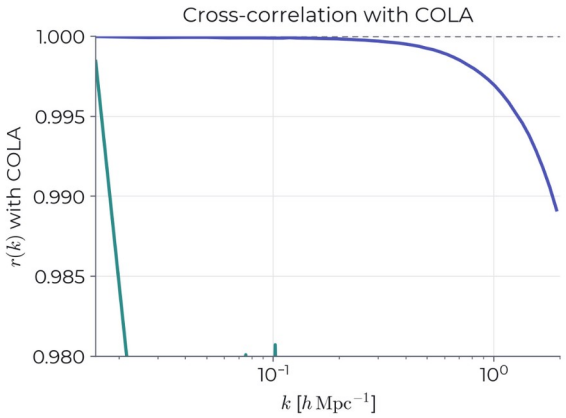
Tassev et al. 2015



Leclercq et al. 2020



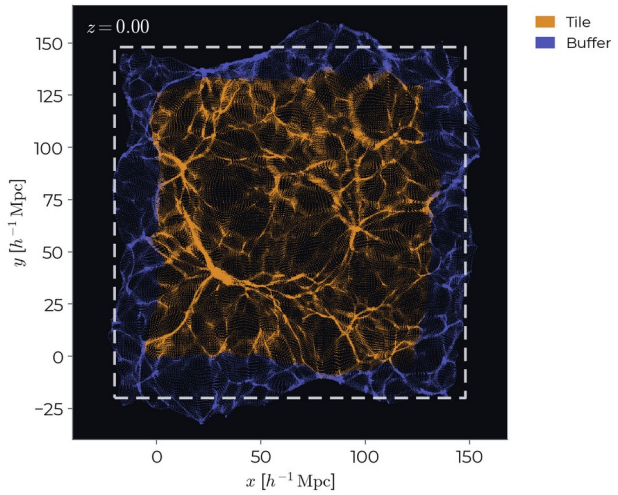




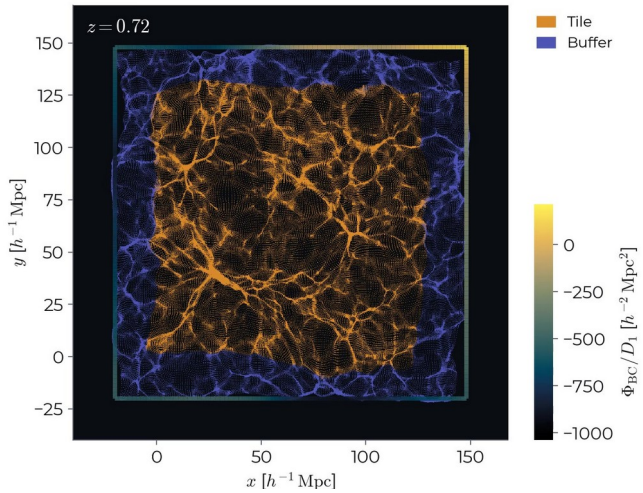
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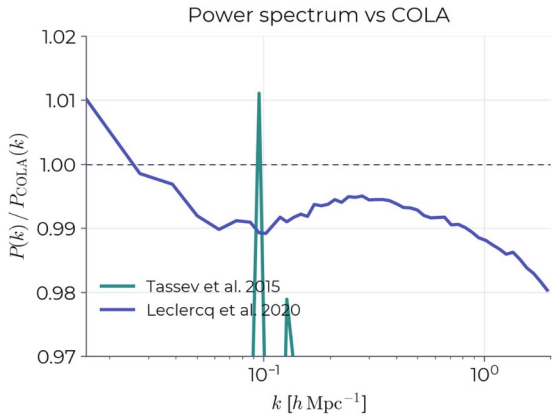
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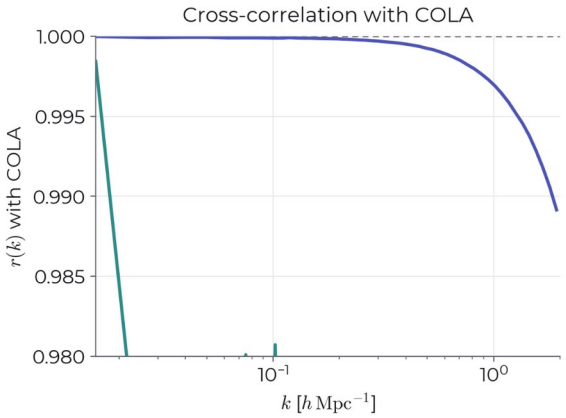
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Leclercq et al. 2020



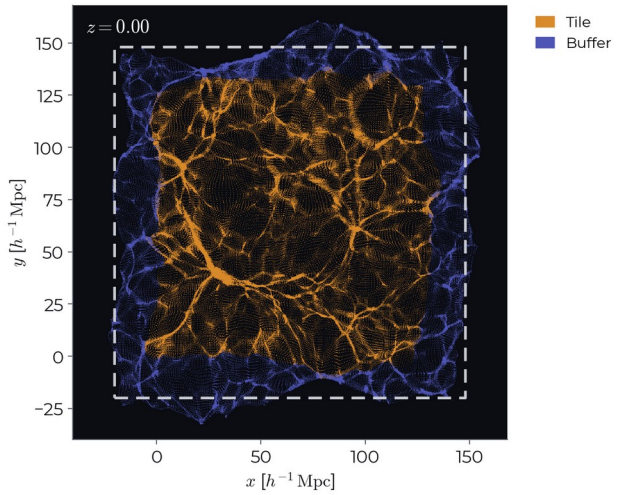




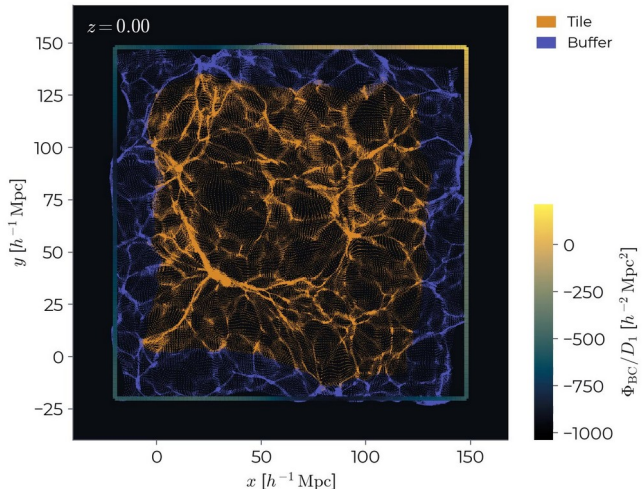
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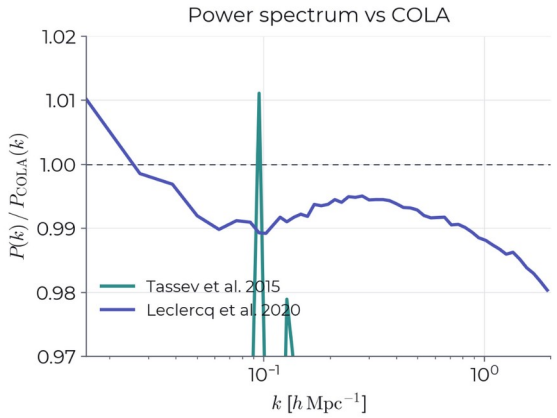
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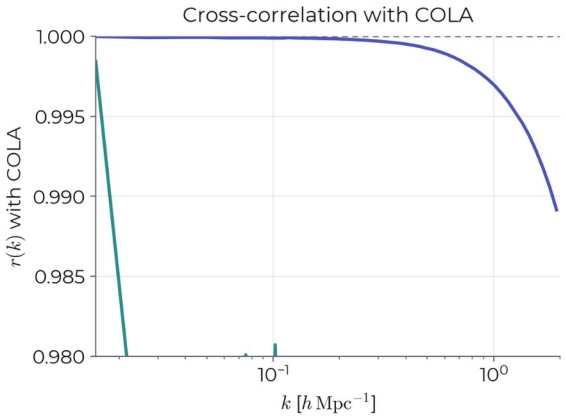
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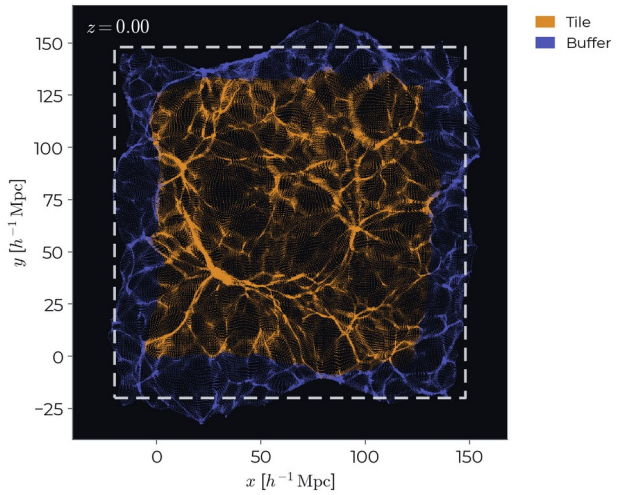




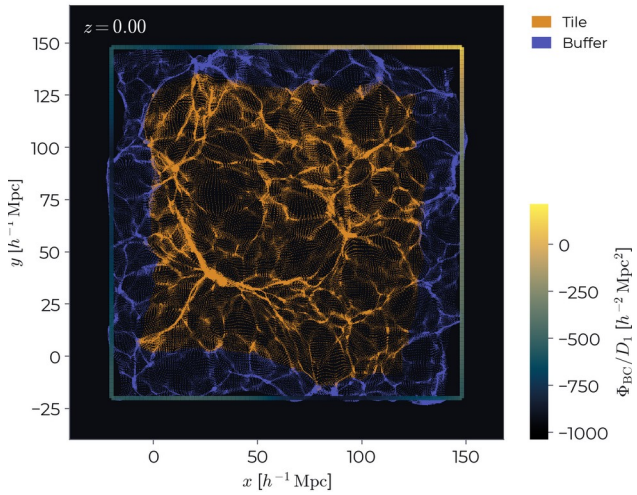
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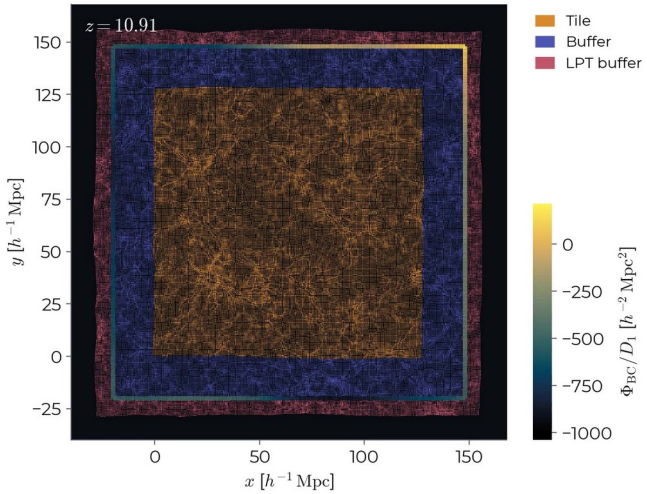
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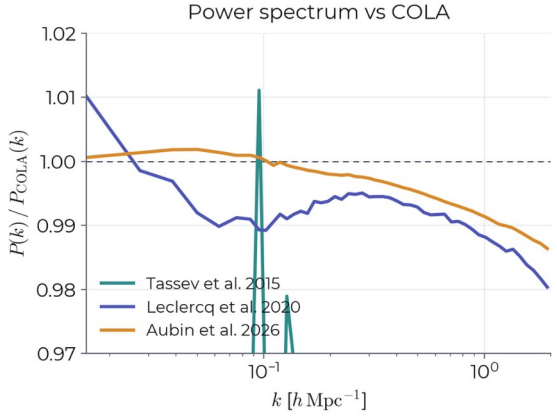


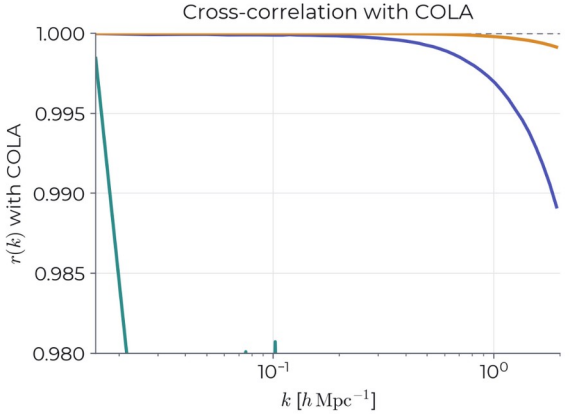
Leclercq et al. 2020



Aubin et al. 2026



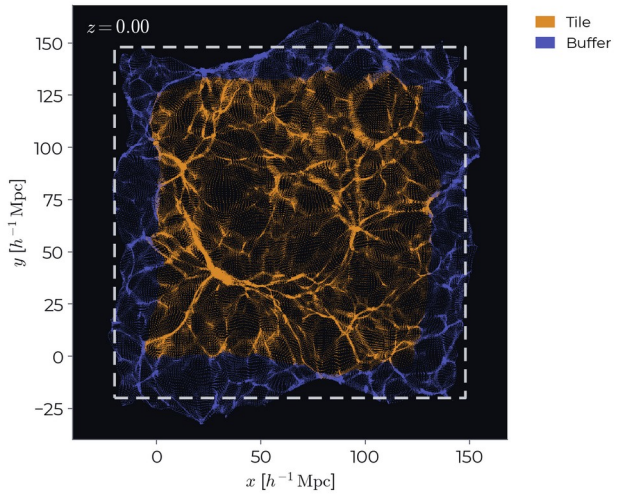




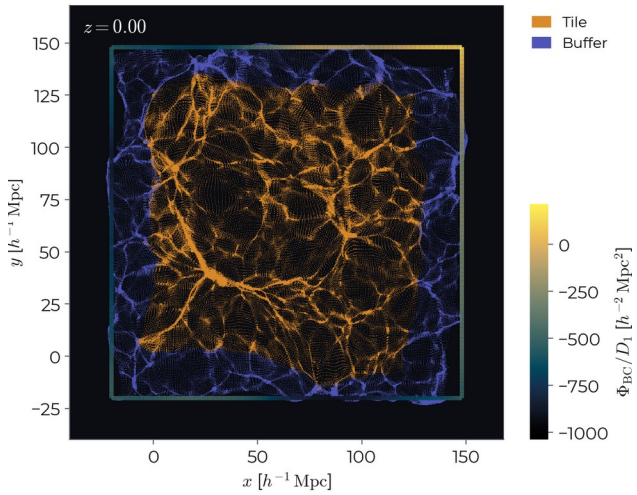
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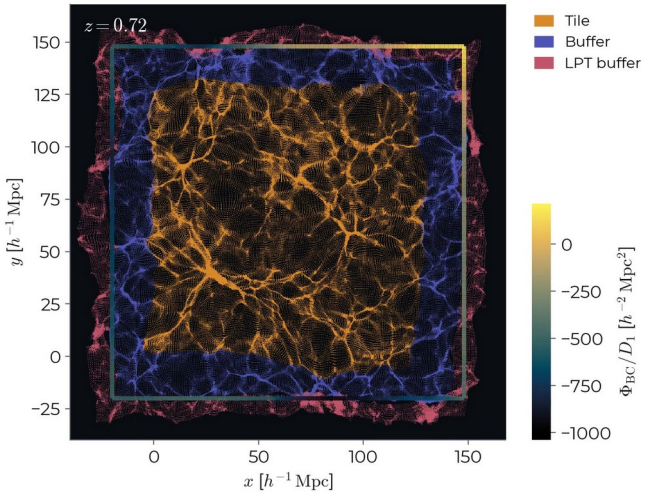
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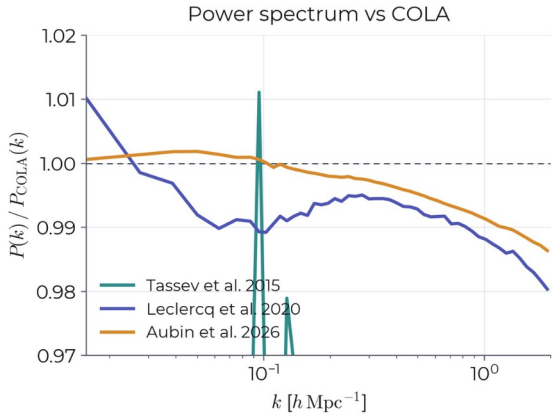


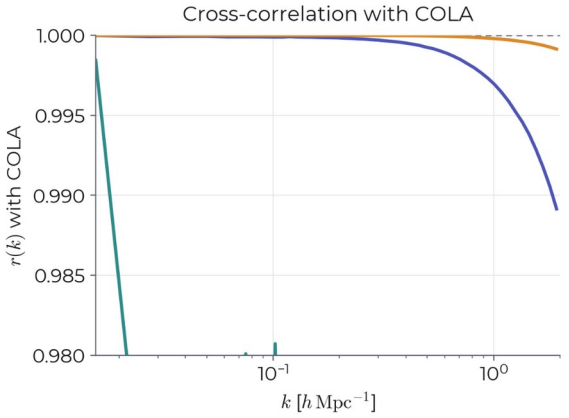
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Aubin et al. 2026



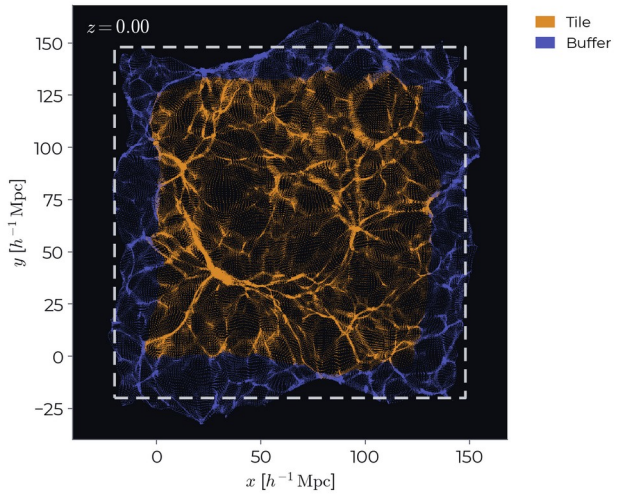




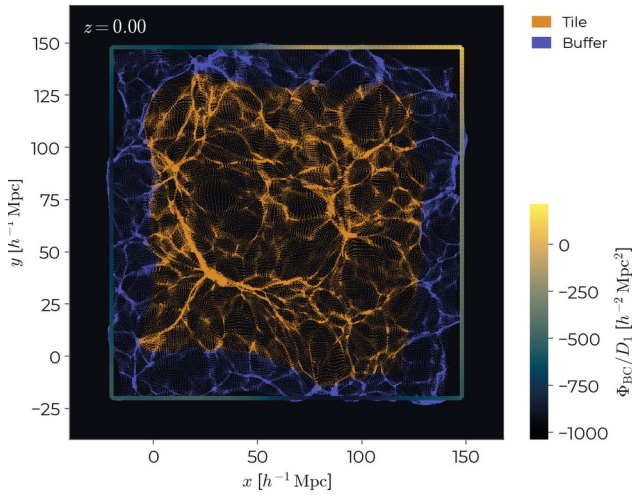
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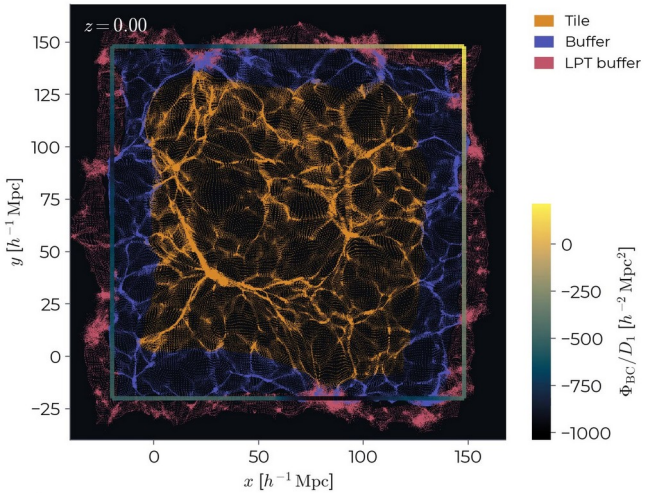
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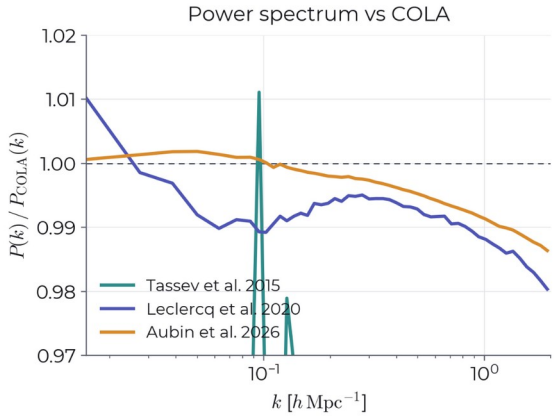


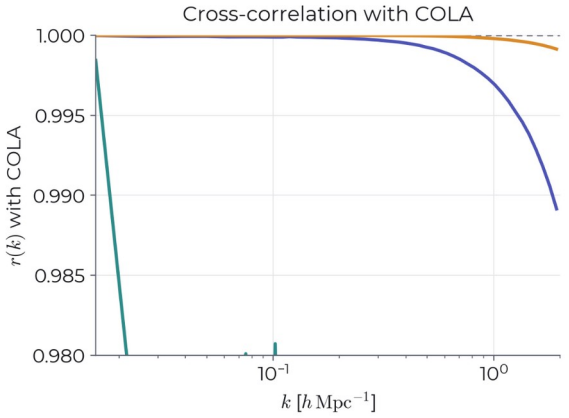
Leclercq et al. 2020



Aubin et al. 2026



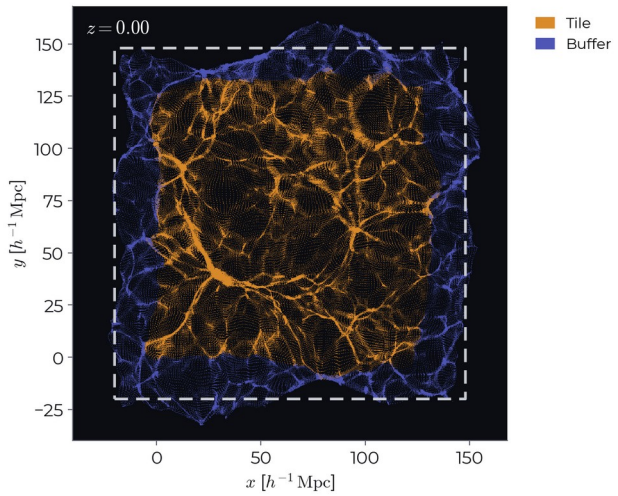




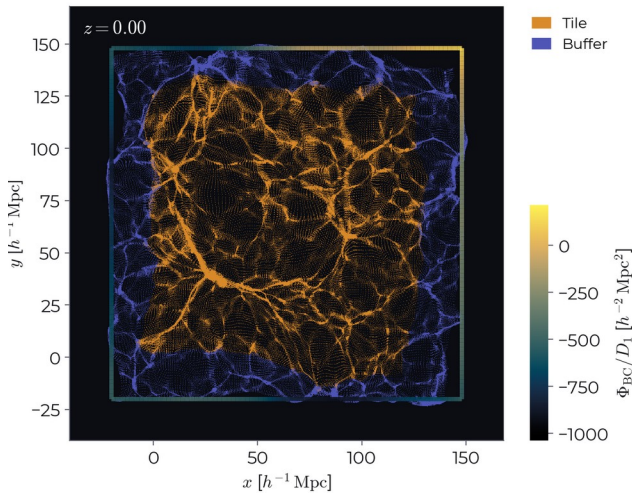
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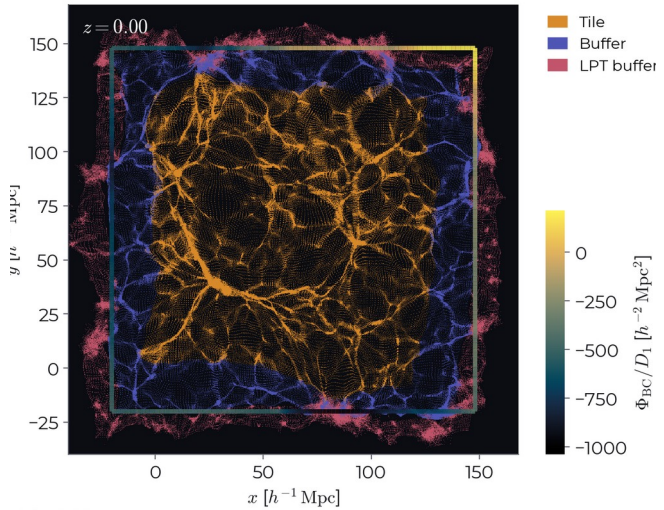
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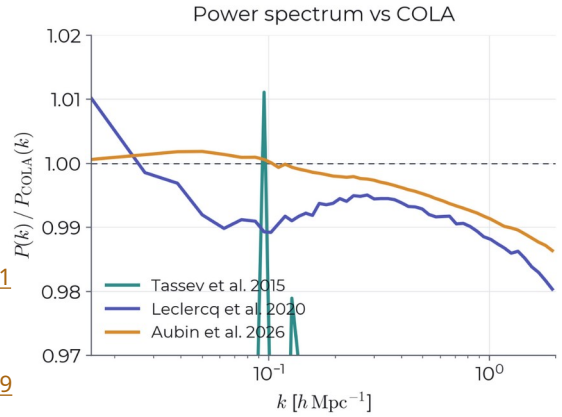


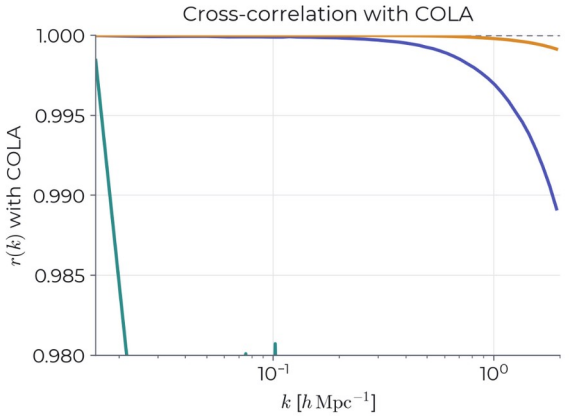
Leclercq et al. 2020



Aubin et al. 2026







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Leclercq F. et al. (2020) · A&A 639, A91 · arXiv:2003.04925
Aubin M. et al. (2026) · preprint · arXiv:2610.26639

sCOLA converges to Gadget4

<1%

deviations on the dark matter power spectra

<1.5%

deviations on the dark matter velocity divergence power spectra

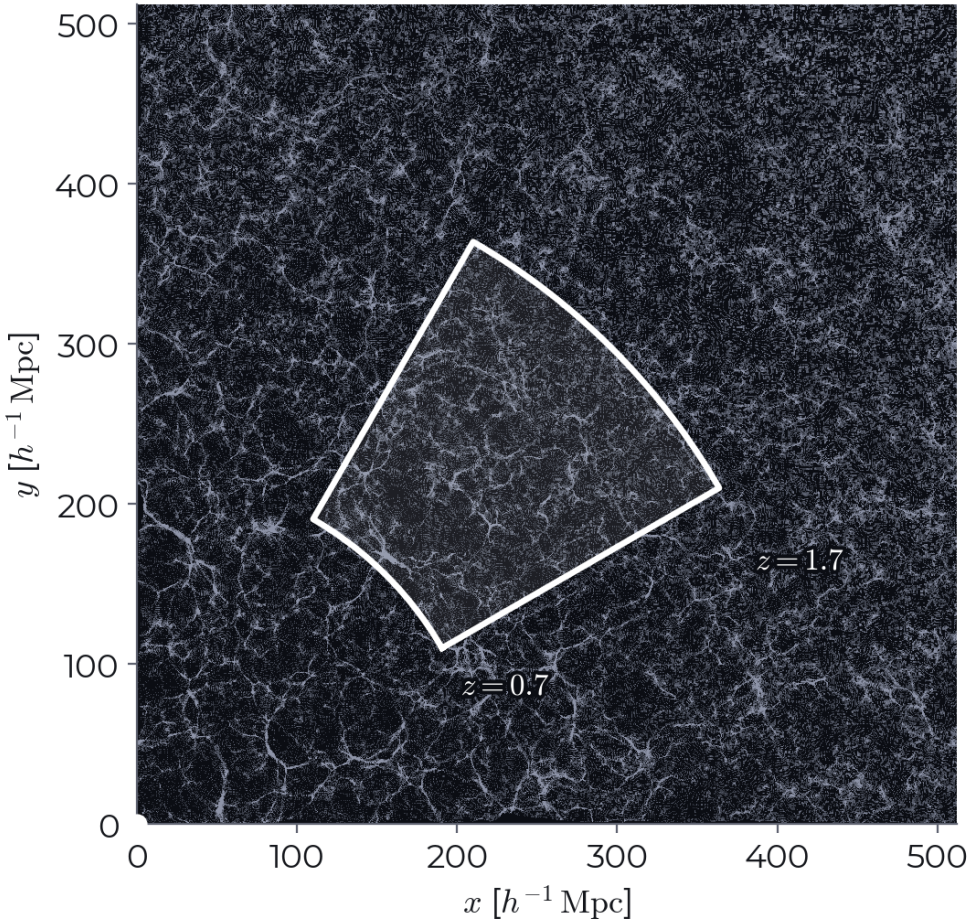
<2%

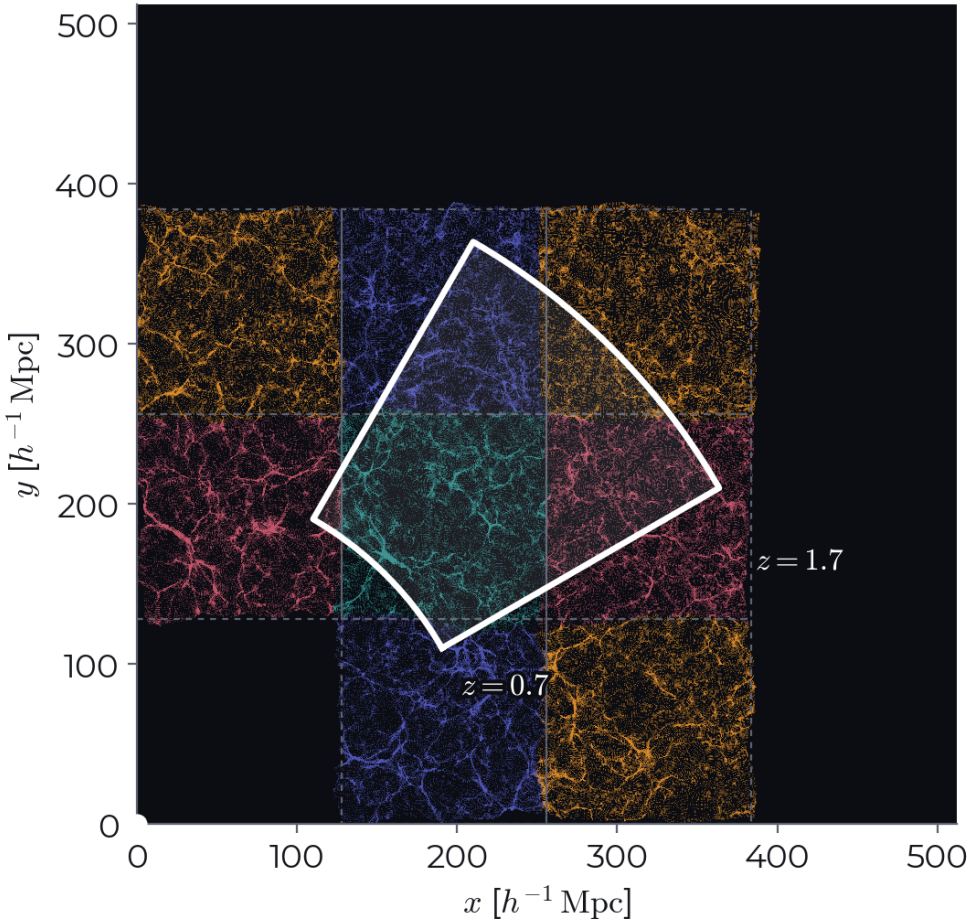
deviations on the dark matter equilateral bispectra

up to $k \sim 0.4\ h/\mathrm{Mpc}$

Aubin M. et al. (2026) · preprint · arXiv:2610.26639

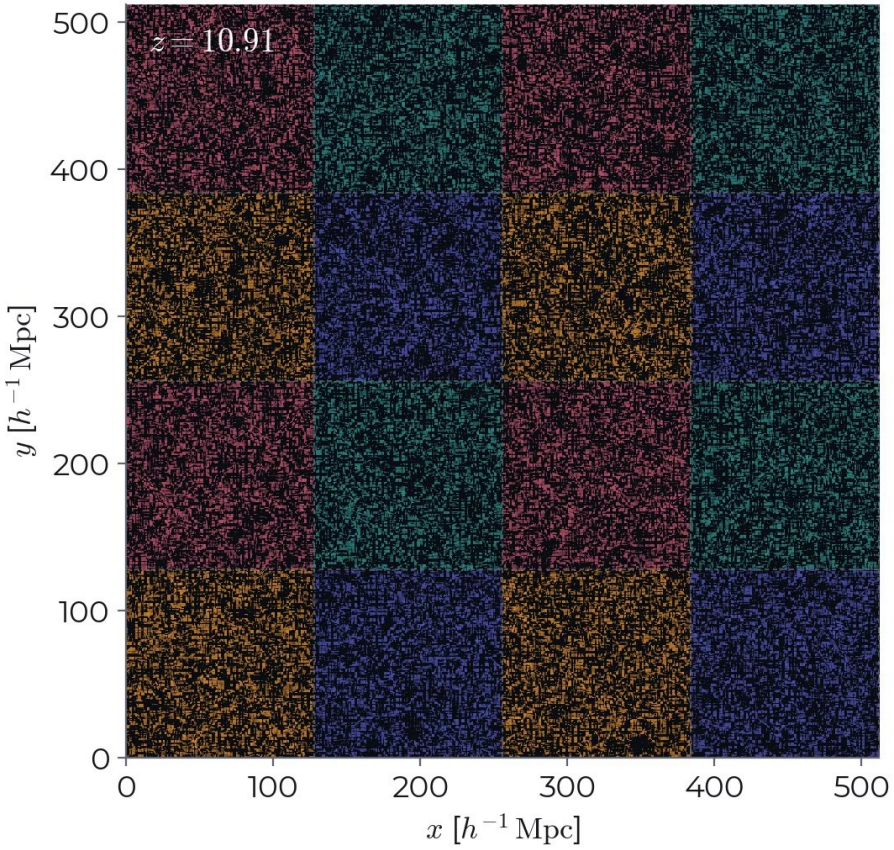
If the tiles are independent, we can evolve only the ones we need!





The lightcone has been exaggerated by a factor 8 for visualisation purposes

With lightcones, we can restrict the evolution to the observed space-time region



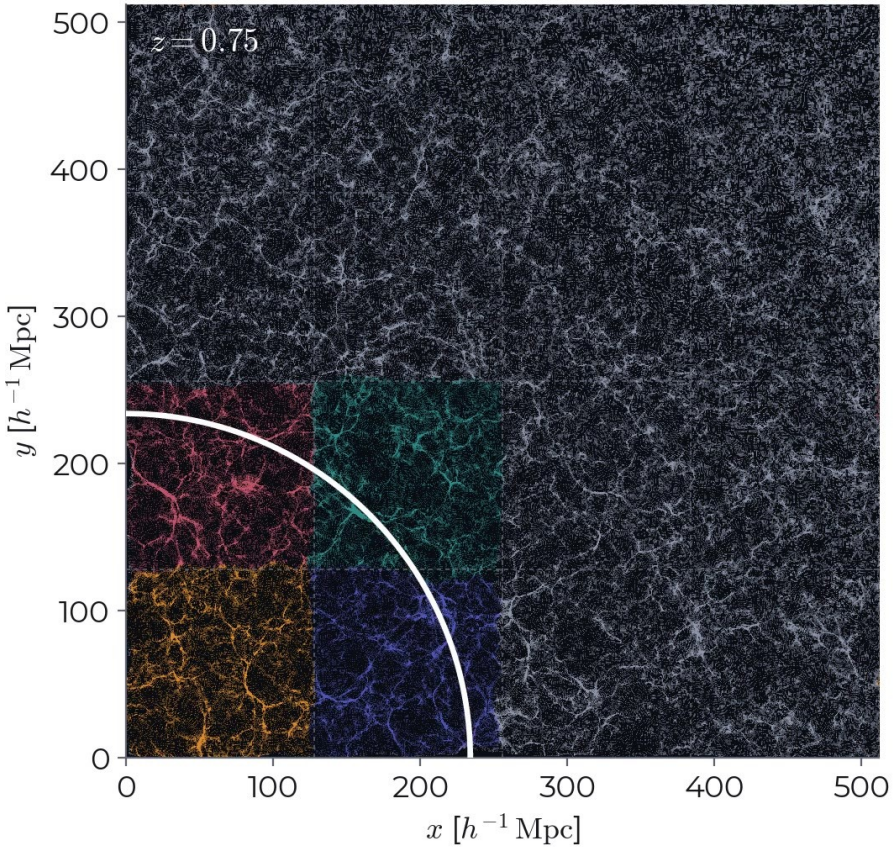
Lightcones production is usually inefficient
In a standard N-body code, the whole box is evolved up to redshift z=0, even the regions that have already been observedv

sCOLA lightcone is efficient!
sCOLA boxes leaving the lightcone are stopped.

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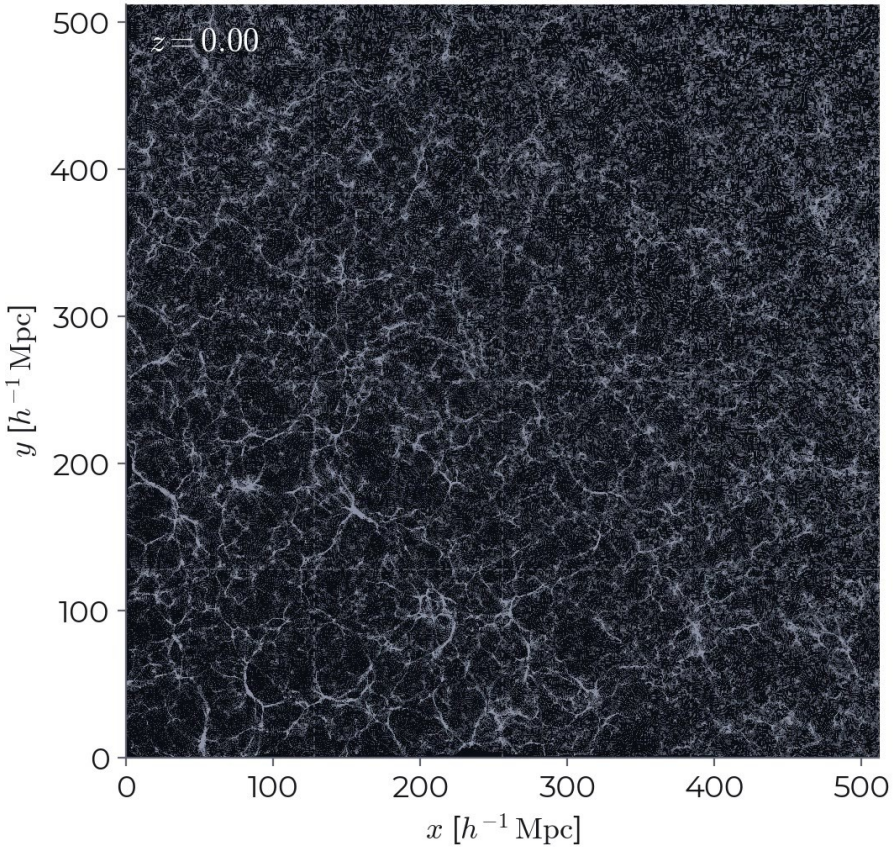
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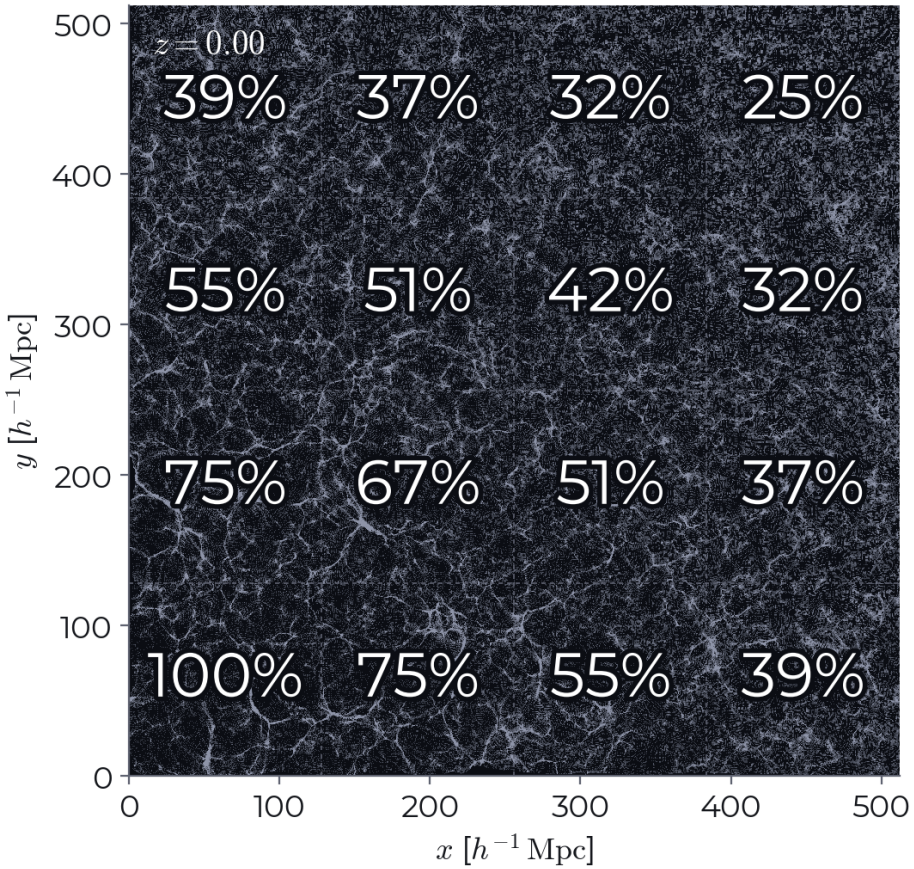
Lightcones production is usually inefficient
In a standard N-body code, the whole box is evolved up to redshift z=0, even the regions that have already been observedv

sCOLA lightcone is efficient!
sCOLA boxes leaving the lightcone are stopped.

Aubin M. et al. (2026) · preprint · arXiv:2610.26639

The lightcone has been exaggerated by a factor 8 for visualisation purposes

With lightcones, we can restrict the evolution to the observed space-time region



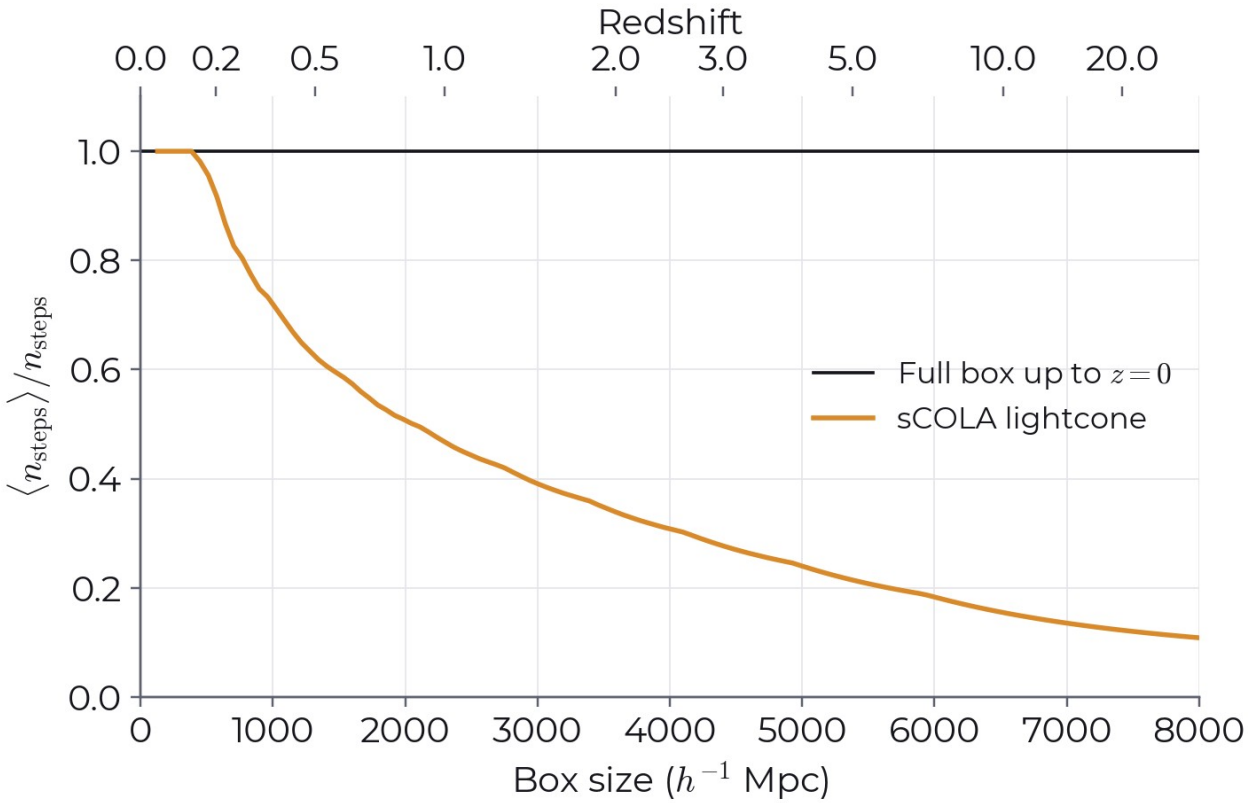
Finished tile

sCOLA lightcone is efficient!
sCOLA boxes leaving the lightcone are stopped.

Aubin M. et al. (2026) · preprint · arXiv:2610.26639

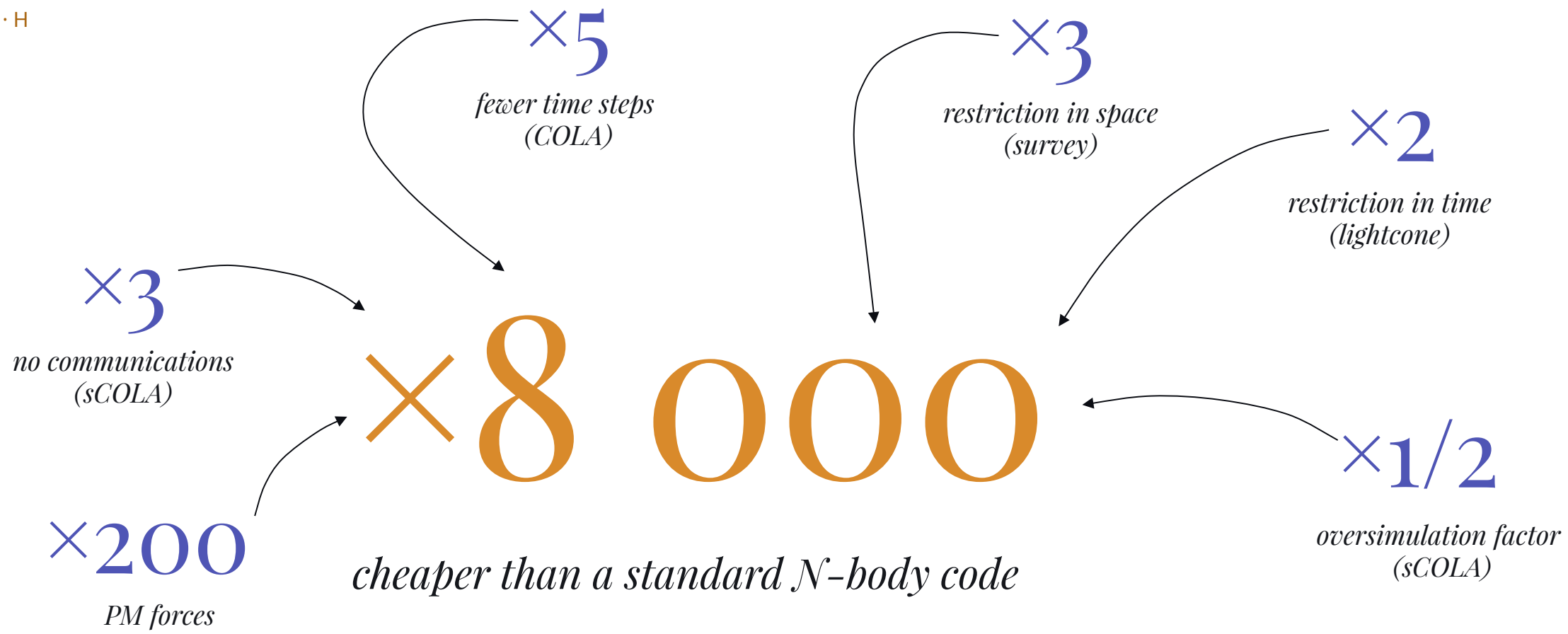
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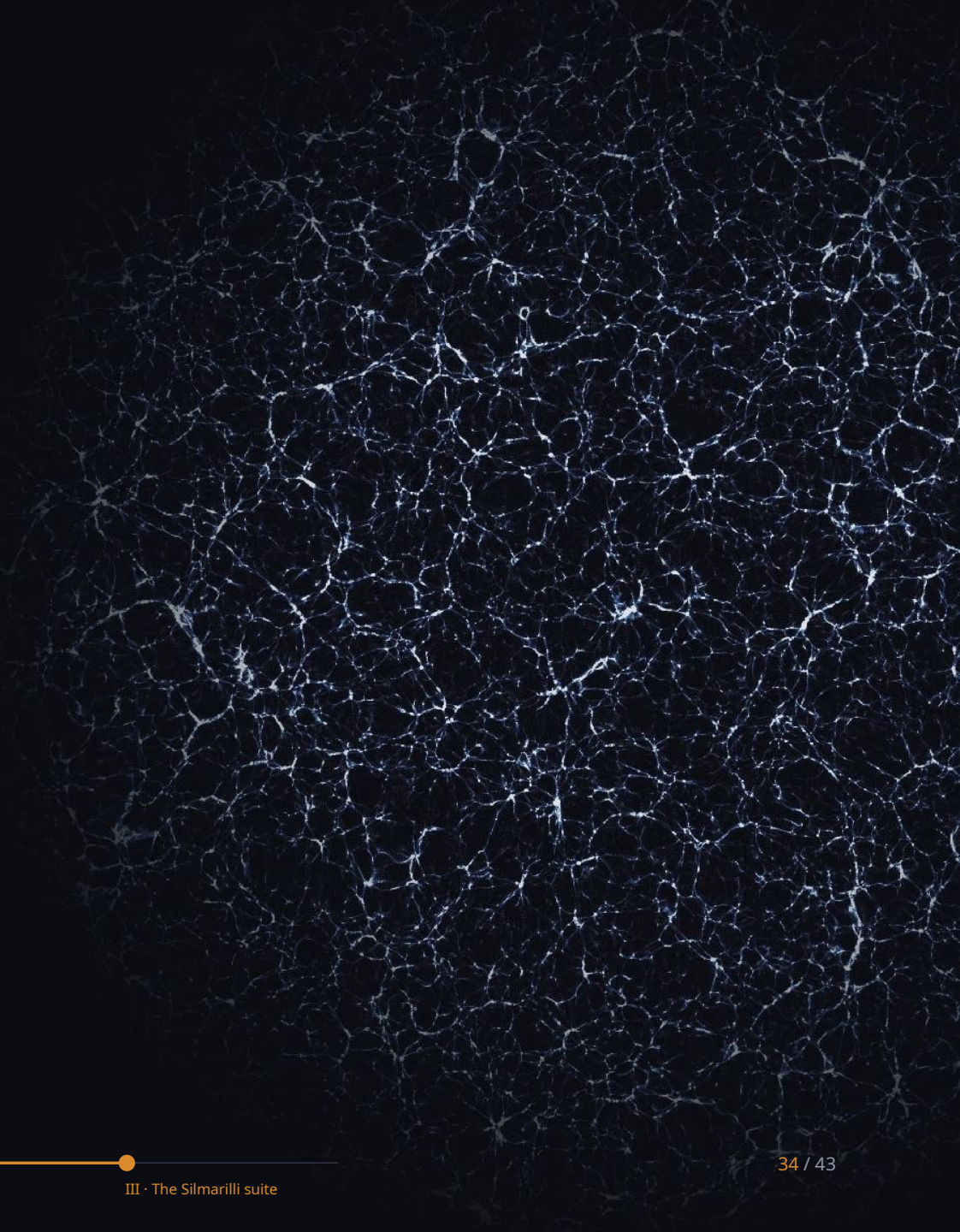
KEY TAKEAWAY · II

Independent tiles mean perfect parallelism: we evolve only what we need, only as long as we need it.

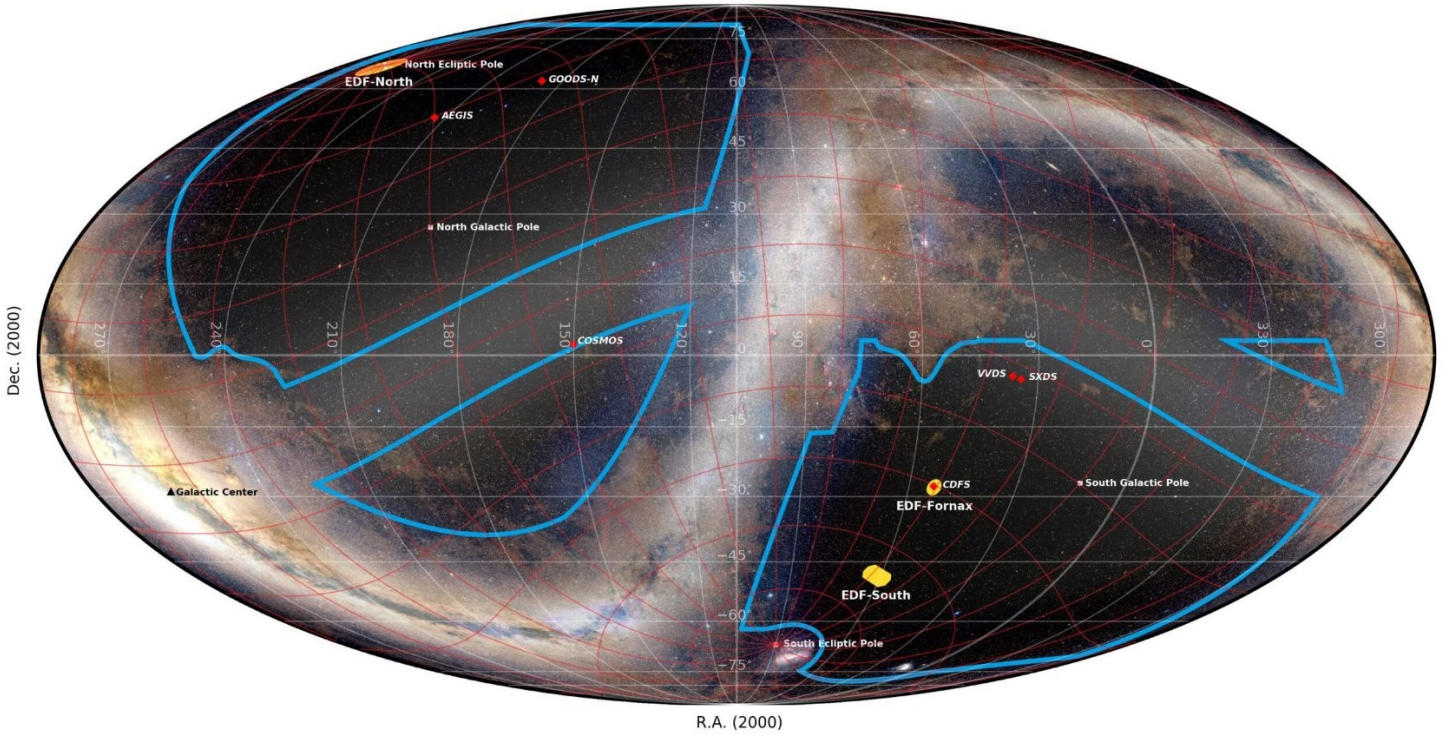
III.

The Silmarilli suite

Applying sCOLA lightcones to the Euclid survey



Euclid will observe 14.5K deg² with 0.84<z<1.88



The 15,000 deg.² Euclid Wide Survey, the 53 deg.² Euclid Deep Survey, and the 6 deep auxiliary fields (6.5 deg.²) [Mollweide Celestial]

Euclid Wide Survey region of interest : 16 Kdeg.² compliant with a 15 Kdeg.² survey

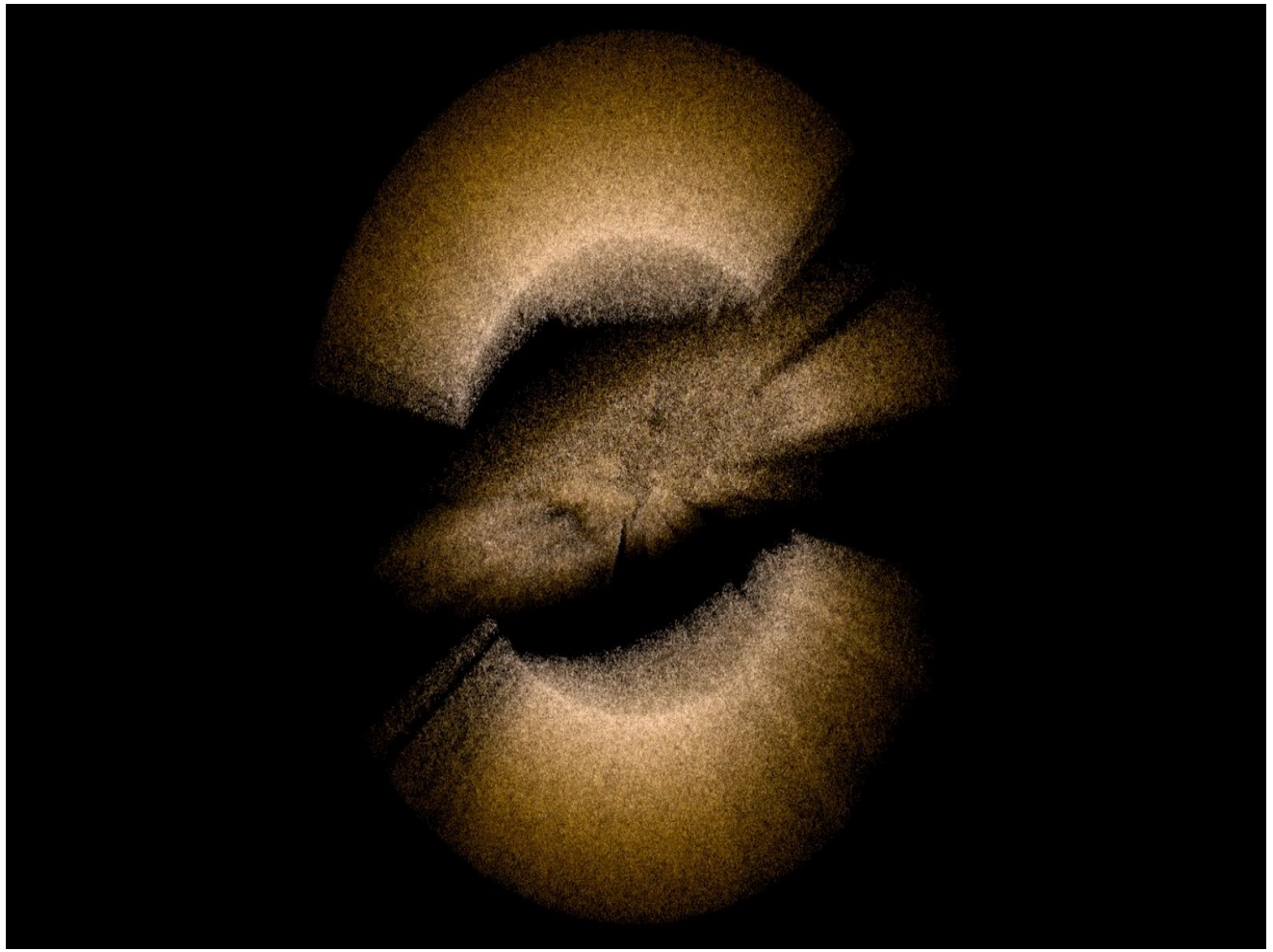
Euclid Deep Fields : North=20 deg.², Fornax=10 deg.², South=23 deg.²

Euclid deep auxiliary fields (GOODSN=0.5, AEGIS=1, COSMOS=2, VVDS=0.5, SXDX=2, CDFS=0.5 deg.²)

Background image: Euclid Consortium / Planck Collaboration / A. Mellinger

Euclid Collaboration et al. (2022) · A&A 662, A112 · doi:10.1051/0004-6361/202141938

Silmarilli Region of Interest contains half of the Euclide Wide Survey

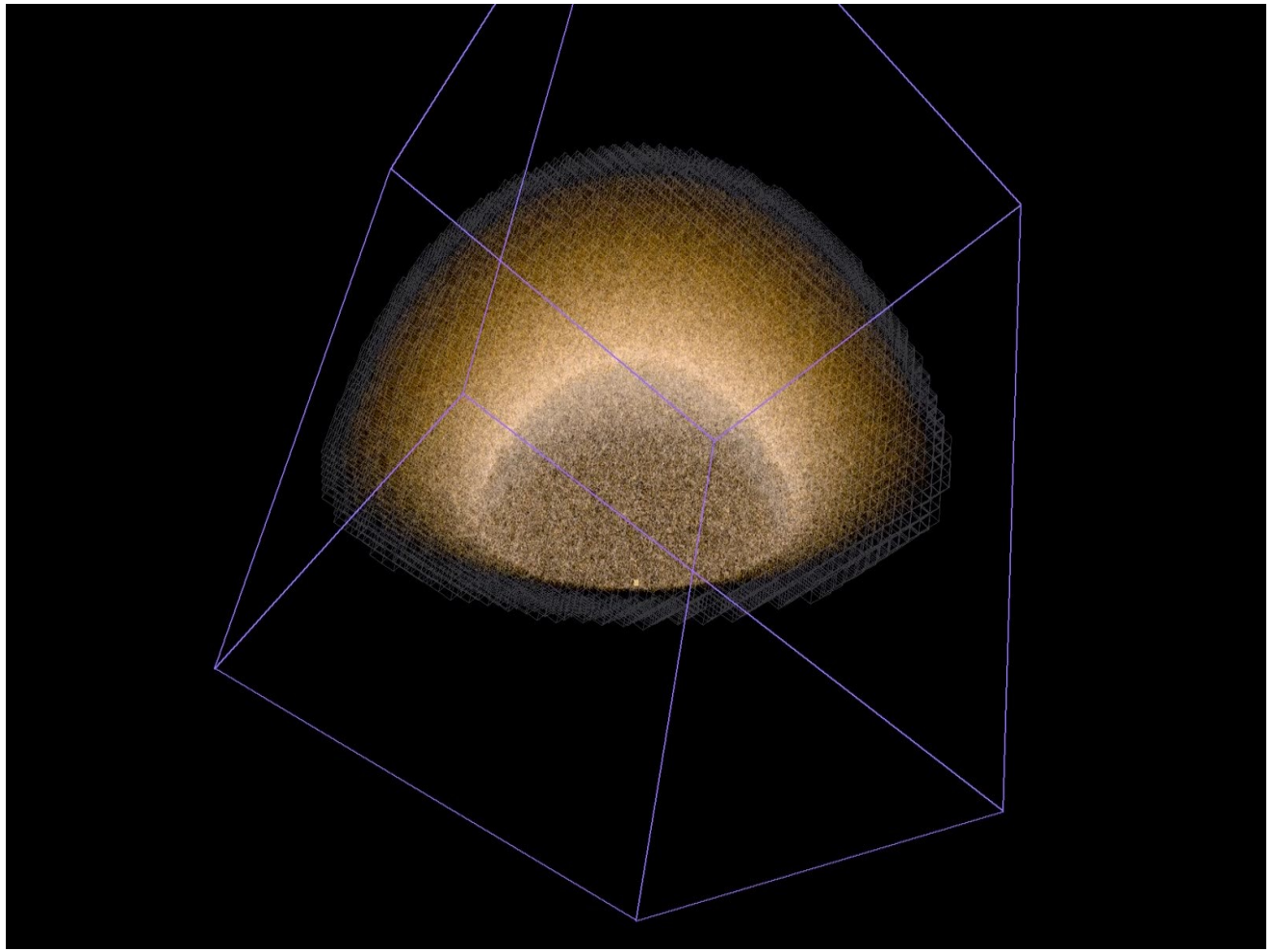


1 970 < R < 3 540 Mpc/h
5.76 Gpc/h bounding cube, 11 520^3 particle grid, complete in the 0.84 < z < 1.88 range

134° angular span
28 377 tiles, 31% of the full volume,
58% lightcone reduction

30 K CPUh per simulation
1.4 K CPUh for initial conditions
22.5 K CPUh for sCOLA lightcone
4.2 K CPUh for halo finder

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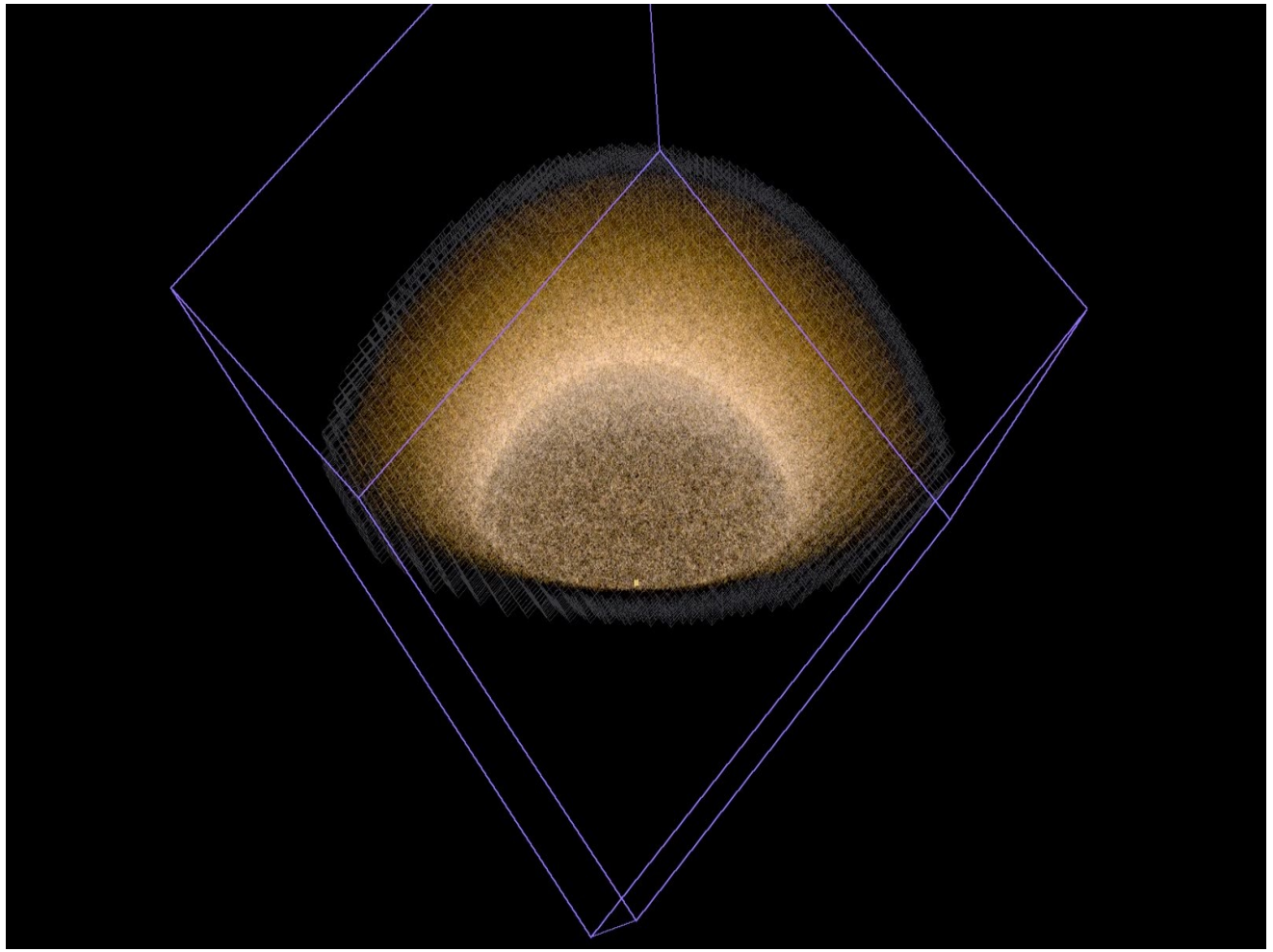


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Our data products

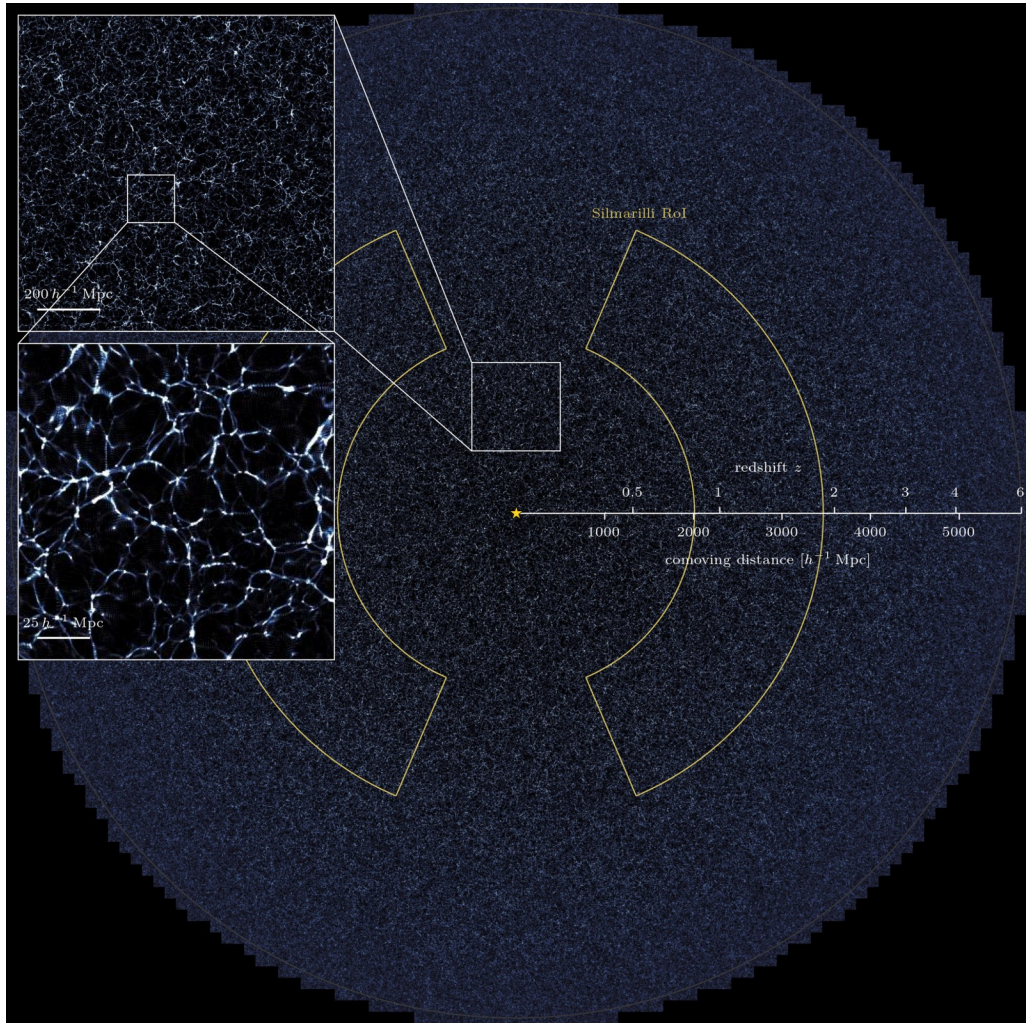
100

independent simulations run

90 GB

per Rockstar halo catalogue

No limits for the size of our simulations (almost...)



Silmaril-Eä : full sky up to redshift 6
11.52 Gpc/h bounding cube, 23 040^3 particle grid

388 744 tiles for 300 K CPUh
Each tile still running on only 4 CPUs

The limit is now on the ICs
We need to run FFTs on the full grid to generate ICs.

Most massive cosmological simulation to date !

Computational costs



PROPERTY	EUCLID FLAGSHIP	GEPETTO	SILMARILLI	SILMARIL-EÄ
Box size	3 600 Mpc/h	1 200 Mpc/h	5 760 Mpc/h	11 520 Mpc/h
Particles	$(16\,000)^3 = 4 \times 10^{12}$	$(2\,160)^3 = 10^{10}$	$(11\,520)^3 \rightarrow 0.84\times 10^{12}$	**$(23\,040)^3 \rightarrow 6.5\times 10^{12}$**
Mass resolution	$10^9\ M_\odot$	$1.5 \times 10^{10}\ M_\odot$	$10^{10}\ M_\odot$	$10^{10}\ M_\odot$
Estimated CPU cost	68 M CPUh	200 CPUh	**30 K CPUh**	390 K CPUh
Estimated RAM cost	240 TB	5.1 TB	4.3 TB | 6 GB	36 TB | 6 GB
TGCC estimated cost	400 K €	1.2 €	180 €	2.3 K €
Estimated carbon footprint	75 tCO2e	0.2 kgCO2e	33 kgCO2e	423 kgCO2e

For the same particle grid, sCOLA lightcone and Pinocchio have approximately the same cost

Euclid Collaboration et al. (2025) · A&A 697, A5 · arXiv:2405.13495
Euclid Collaboration et al. (2025) · A&A 704, A306 · arXiv:2507.12116

You can explore Eä yourself!

https://mayeulaubin.github.io/eaviz/

Also available in VR!
You can explore in “Sky” mode, fixed at the observer; or in “Fly” mode, moving around. Rockstar halos, dark matter density redshift slabs, and DisperSE cosmic web!



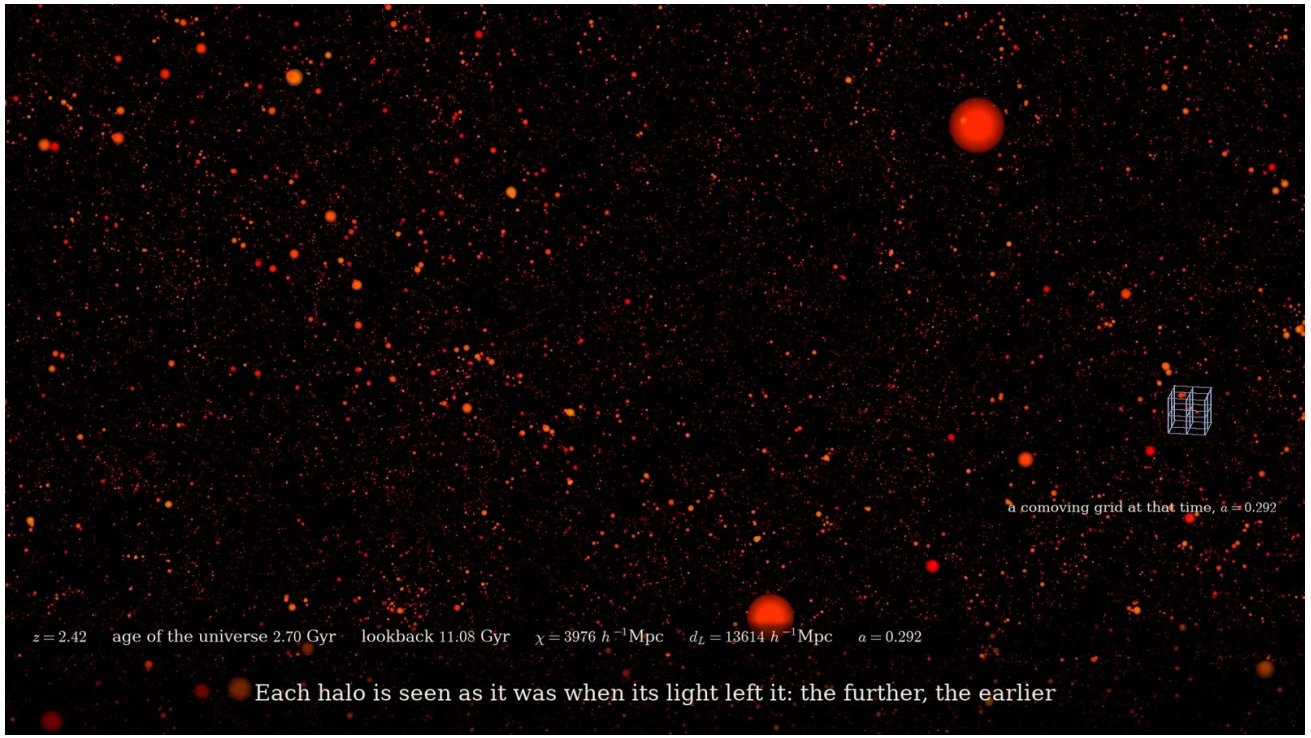


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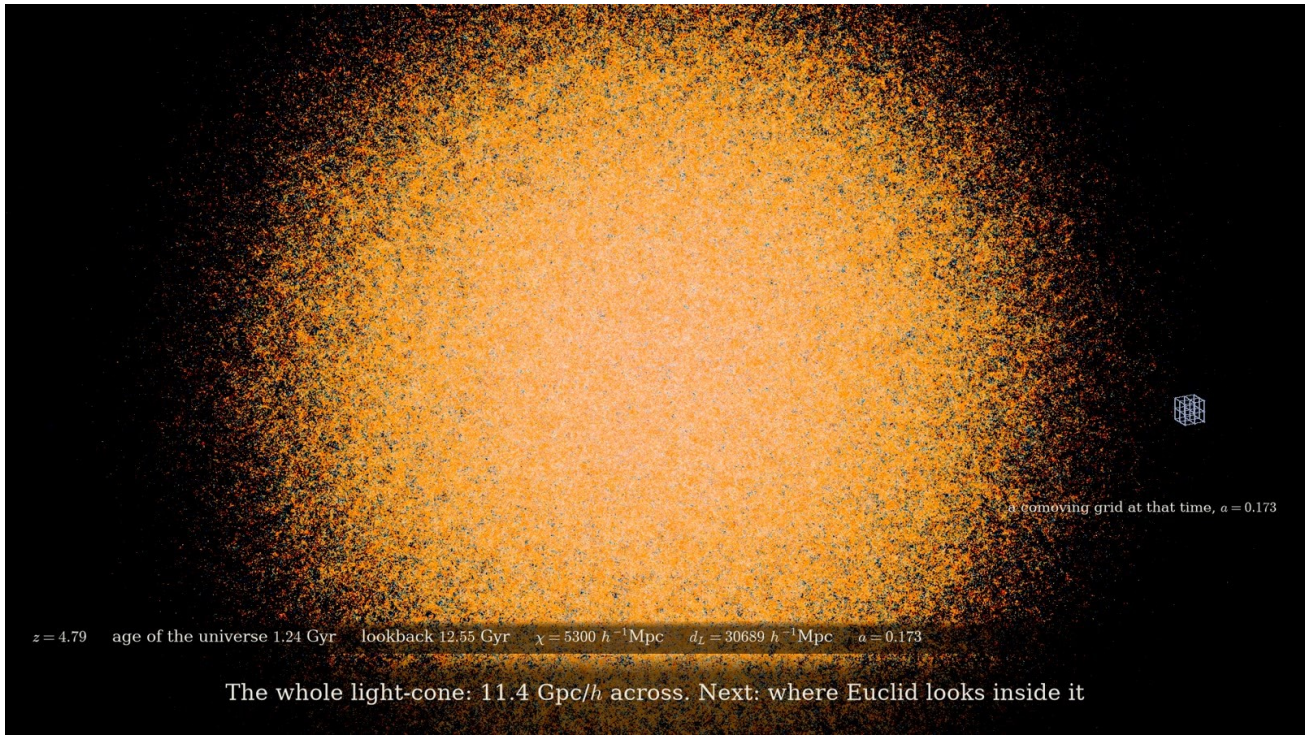


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KEY TAKEAWAY · III

sCOLA lightcone is unlocking access to cheap arbitrarily large cosmological simulations



CONCLUSION

I. N-body simulations are necessary for the analysis of cosmological surveys, but they are too expensive

II. We validated sCOLA at the percent level accuracy. It splits the volume into independent tiles: we can simulate only what we observe, without communications

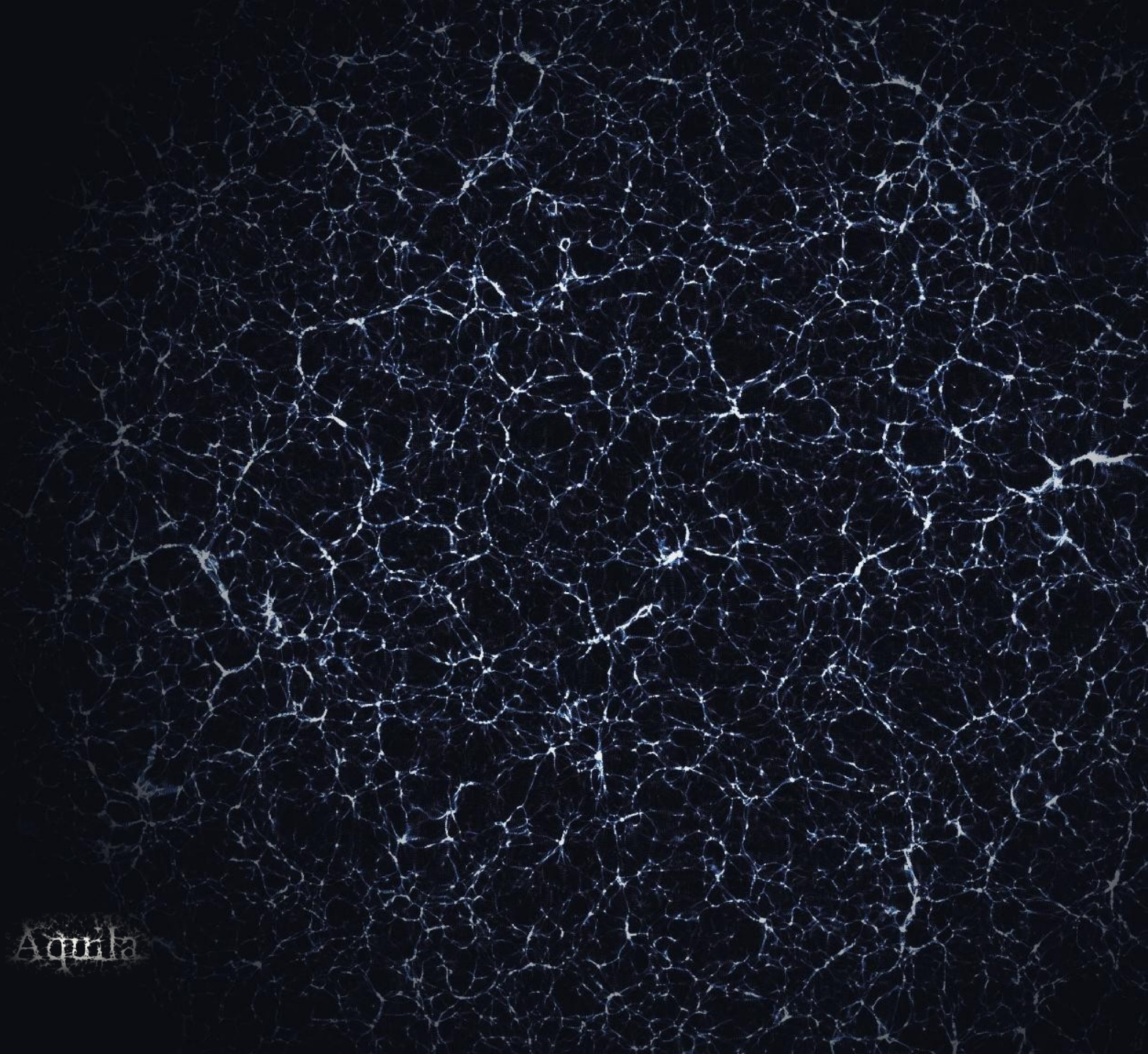
III. We produced 100 simulations of half of the Euclid Wide Survey with a small budget, and also the largest cosmological simulation to date

Thank you

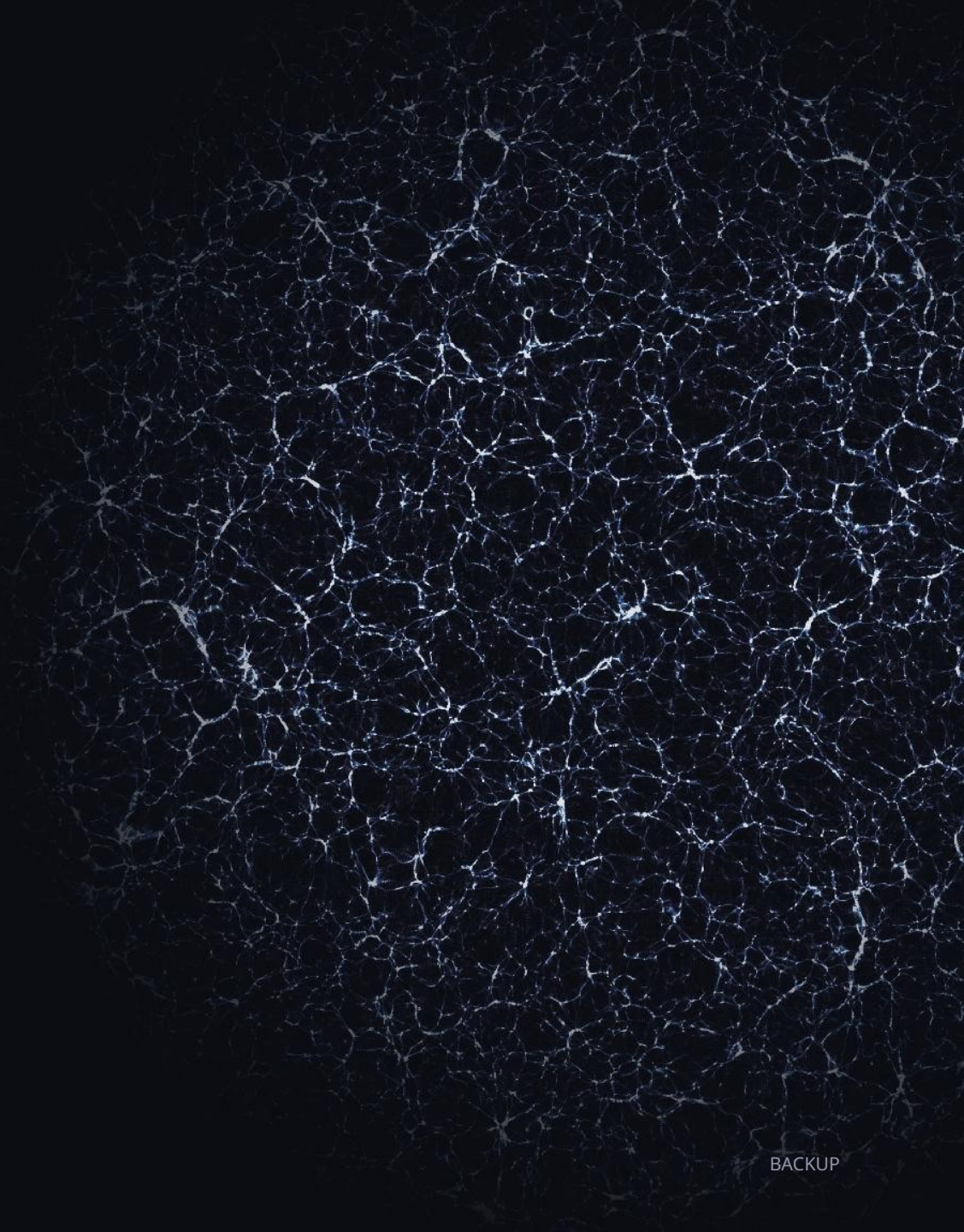
Questions?

mayeul.aubin@iap.fr

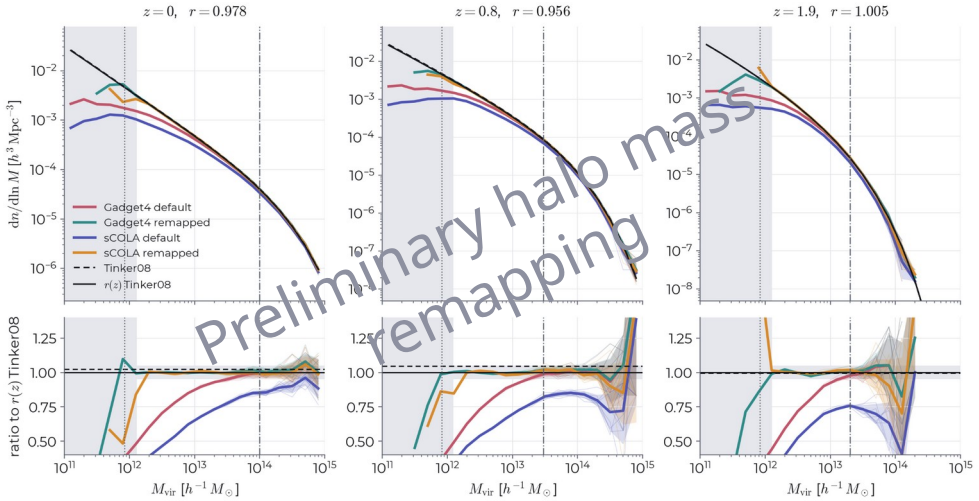
github.com/MayeulAubin · mayeulaubin.github.io/eaviz/

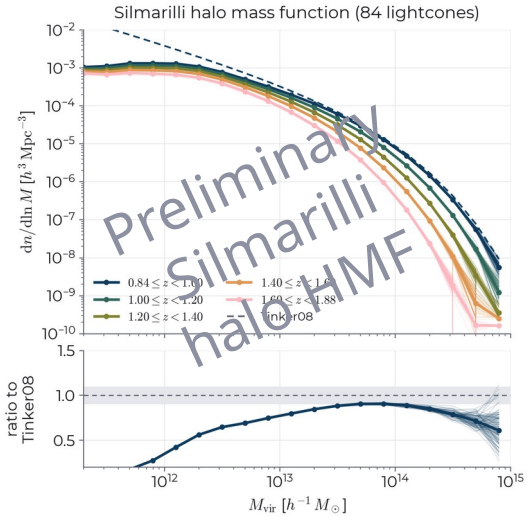


Backup slides



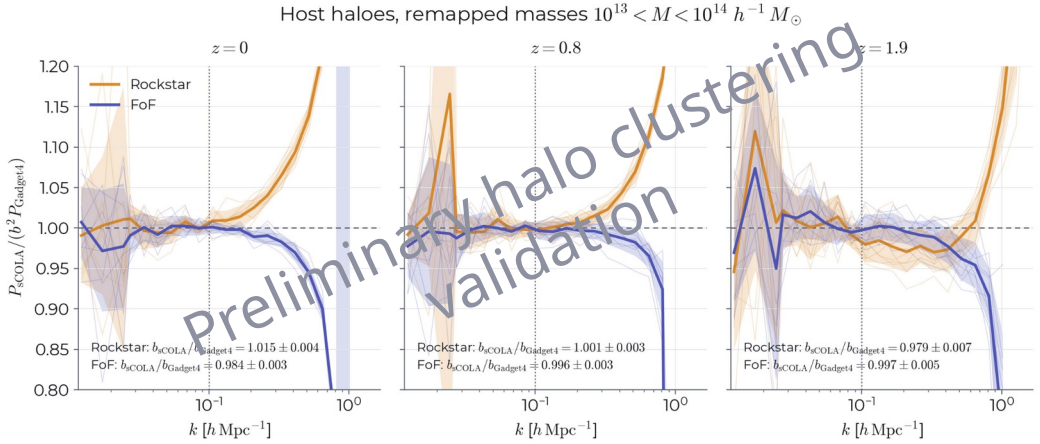
We aim for halos accurate above ~ 10^{12} $M_\odot$

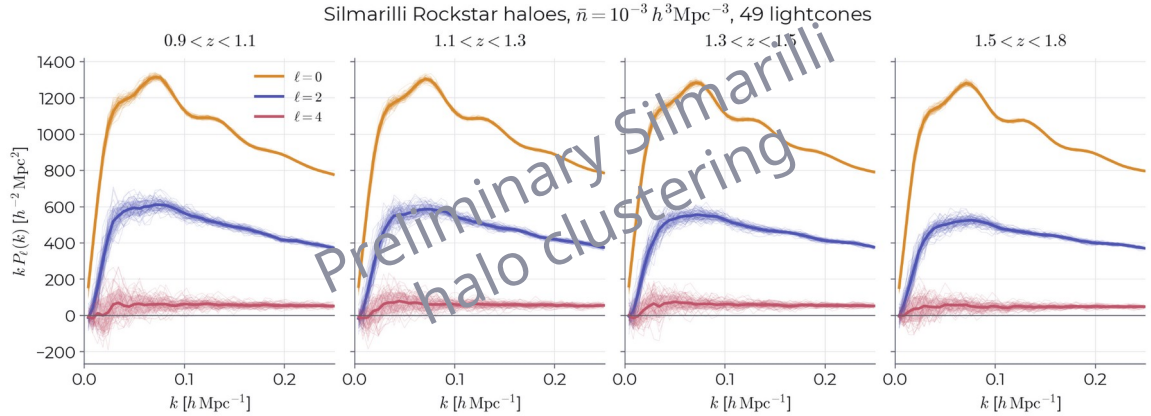




We need halo mass remapping
Rockstar sCOLA halo mass function deviates from Tinker08

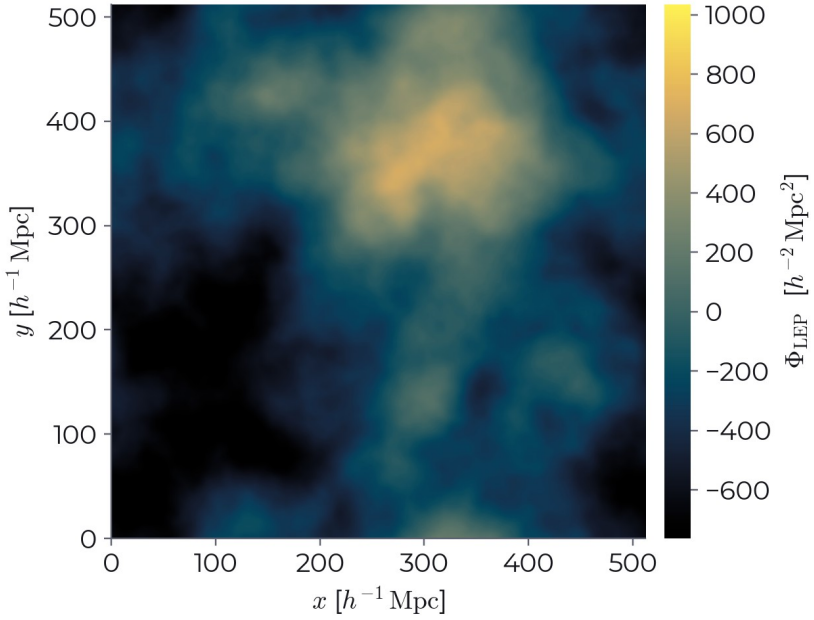
Maybe galaxies with HOD?
Provided that we find a calibrated HOD model, we could release galaxies catalogues



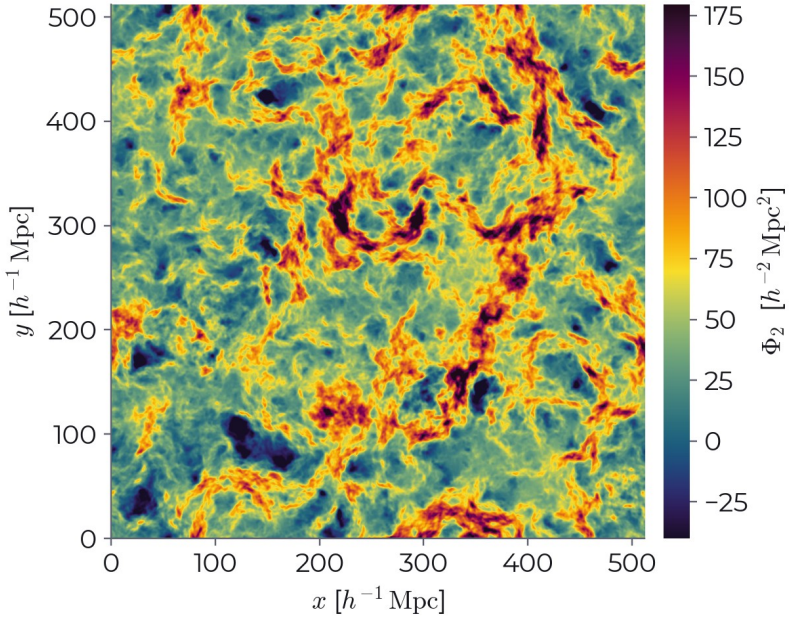


2nd order gravitational potential

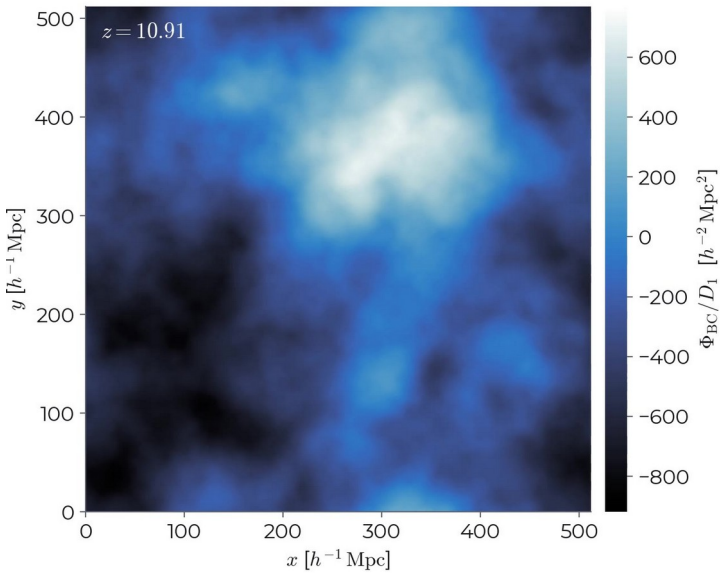
First order term



Second order term



Total potential



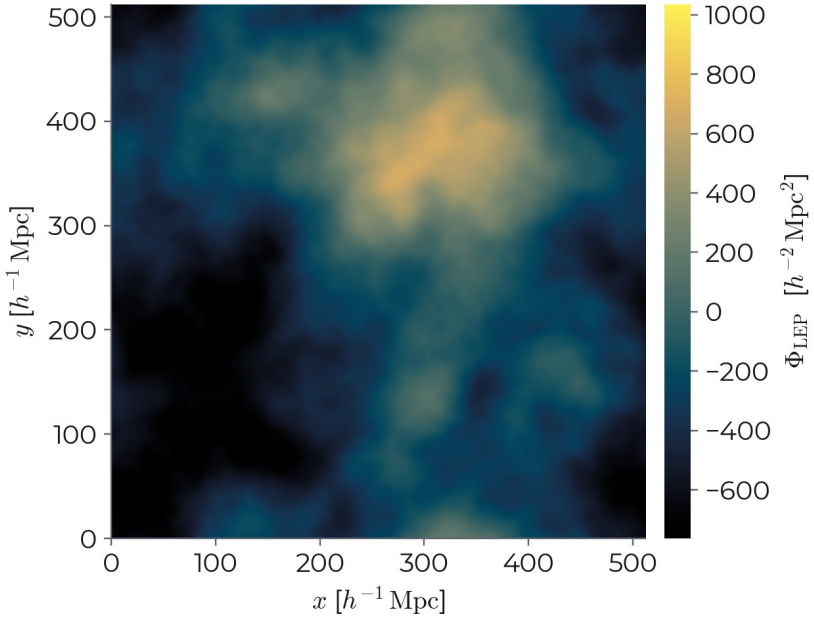
$$\Phi_1(\mathbf{q}) = \phi_1^{\mathrm{LPT}}(\mathbf{q})$$

$$\Phi_2(\mathbf{q}) = \frac{10}{7}\phi_2^{\mathrm{LPT}}(\mathbf{q}) + \frac{1}{2}\|\mathbf{\Psi}_1^{\mathrm{LPT}}(\mathbf{q})\|^2$$

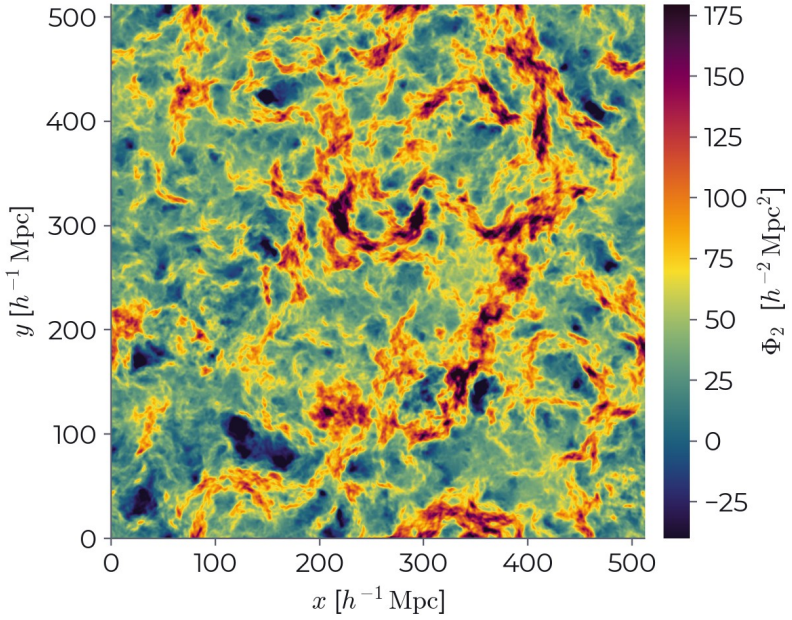
$$\Phi^{\mathrm{BCs}}(\mathbf{q}, a) = D_1(a)\Phi_1(\mathbf{q}) + (D_1(a))^2\,\Phi_2(\mathbf{q})$$

2nd order gravitational potential

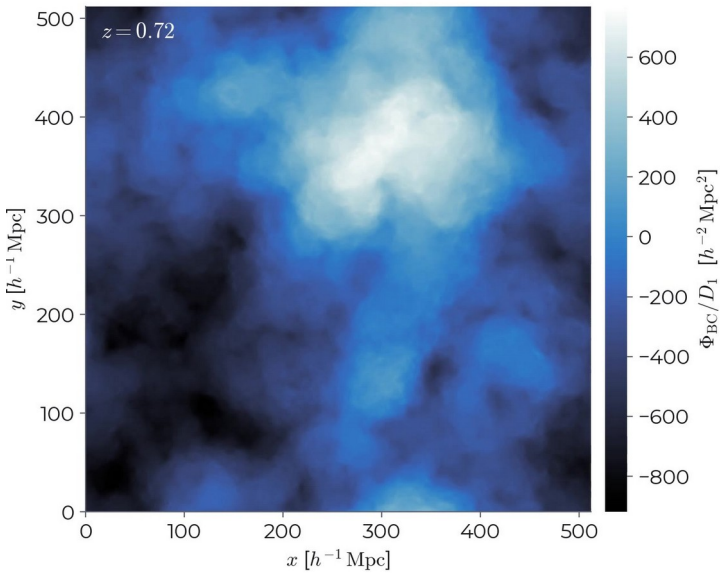
First order term



Second order term



Total potential



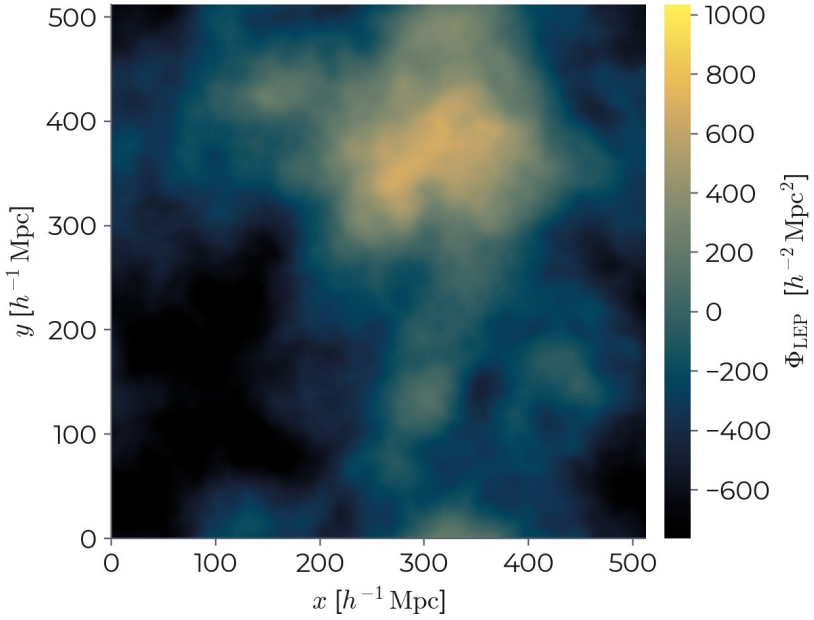
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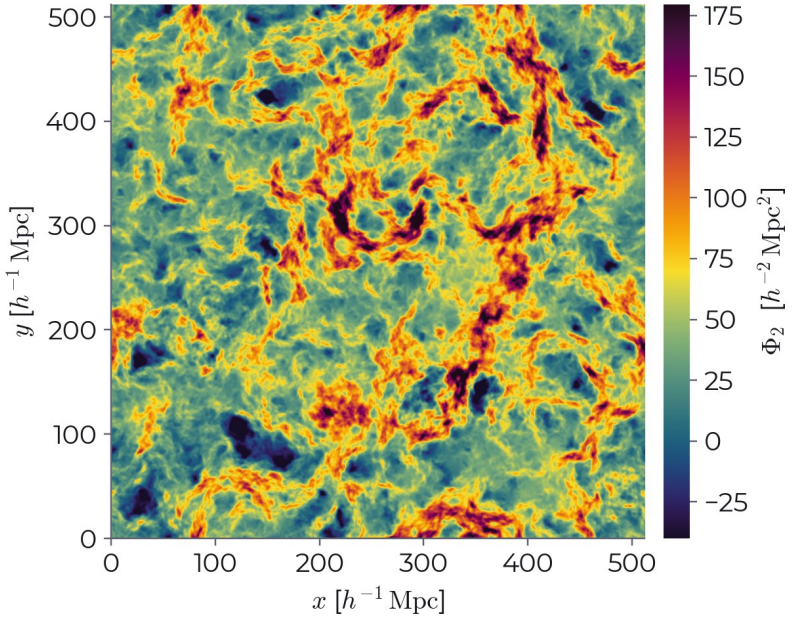
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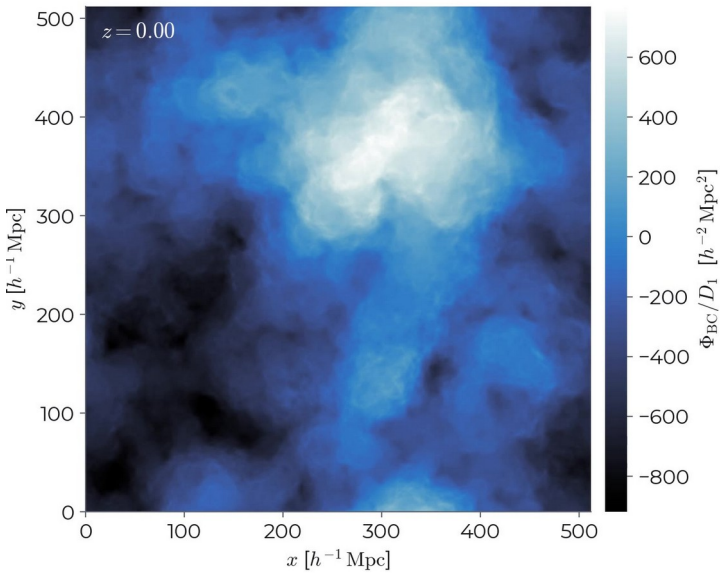
First order term



Second order term



Total potential



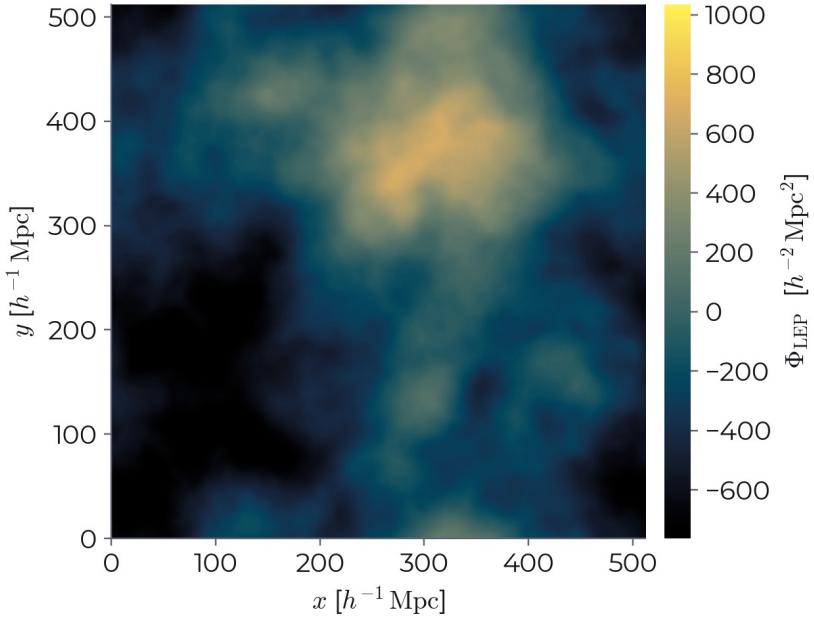
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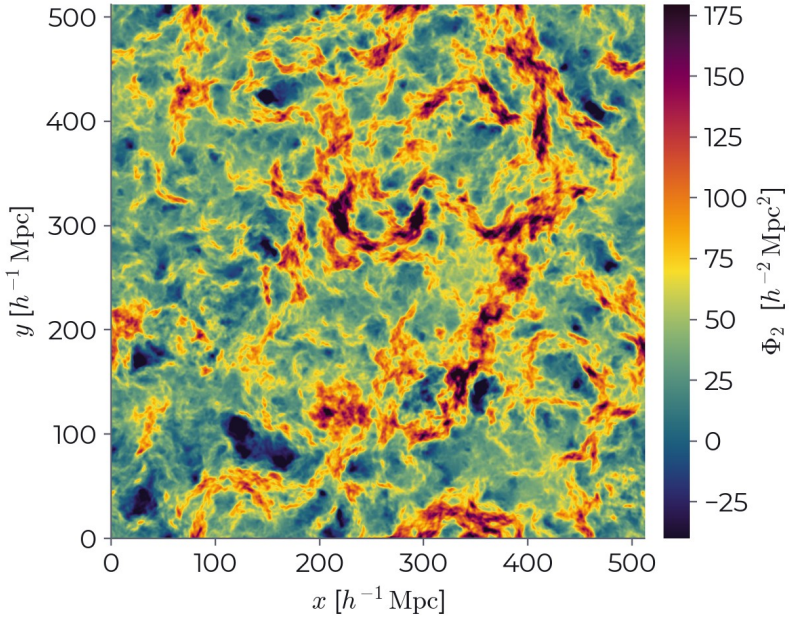
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2nd order gravitational potential

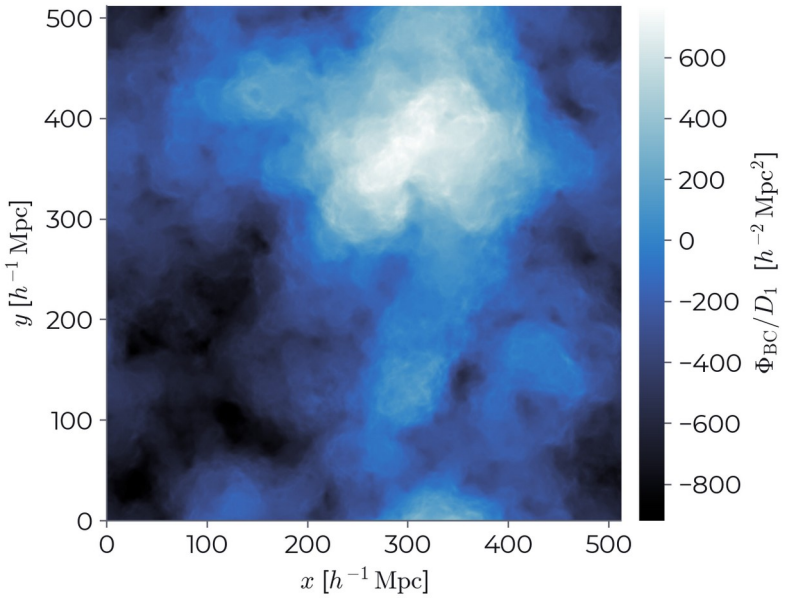
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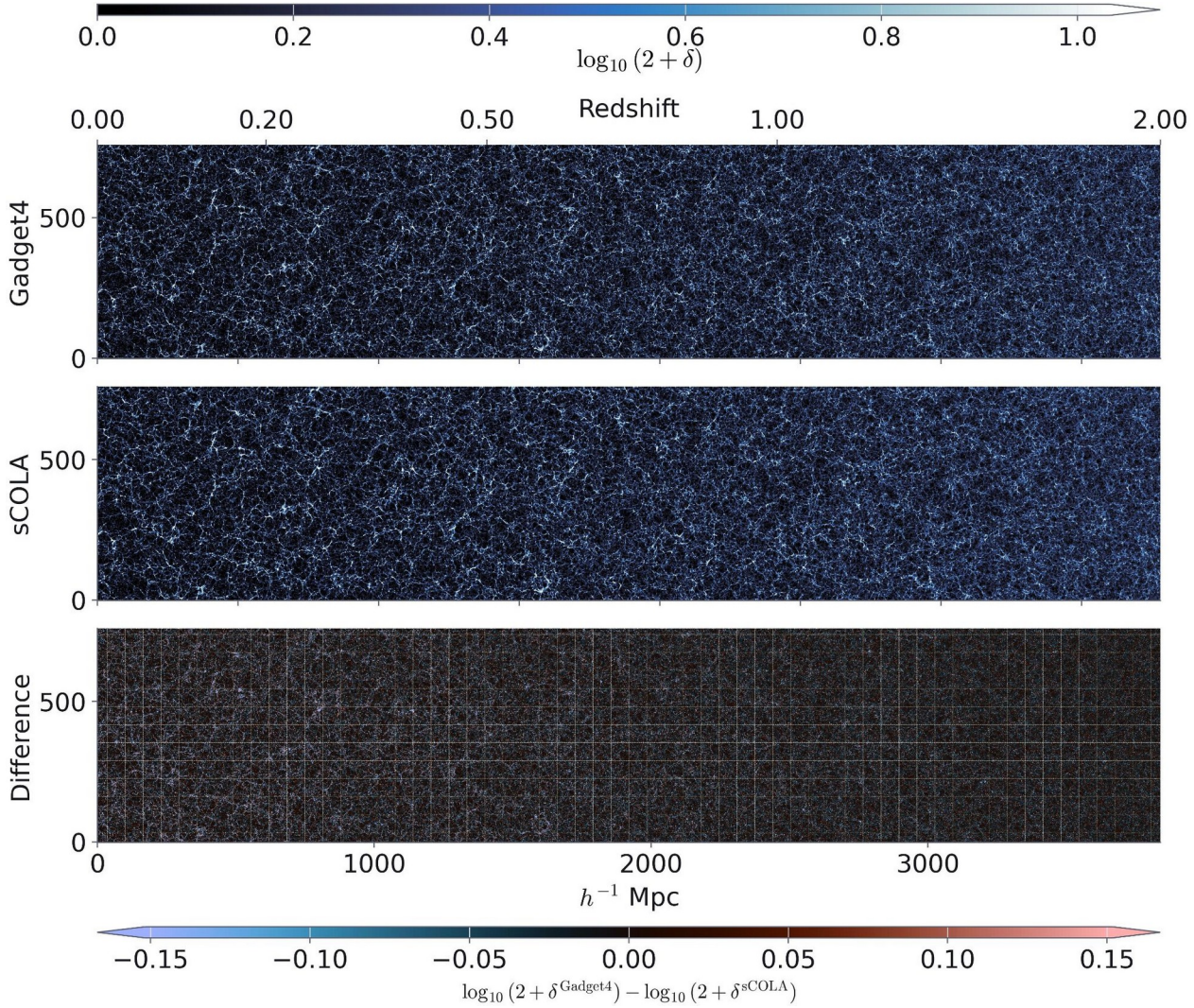


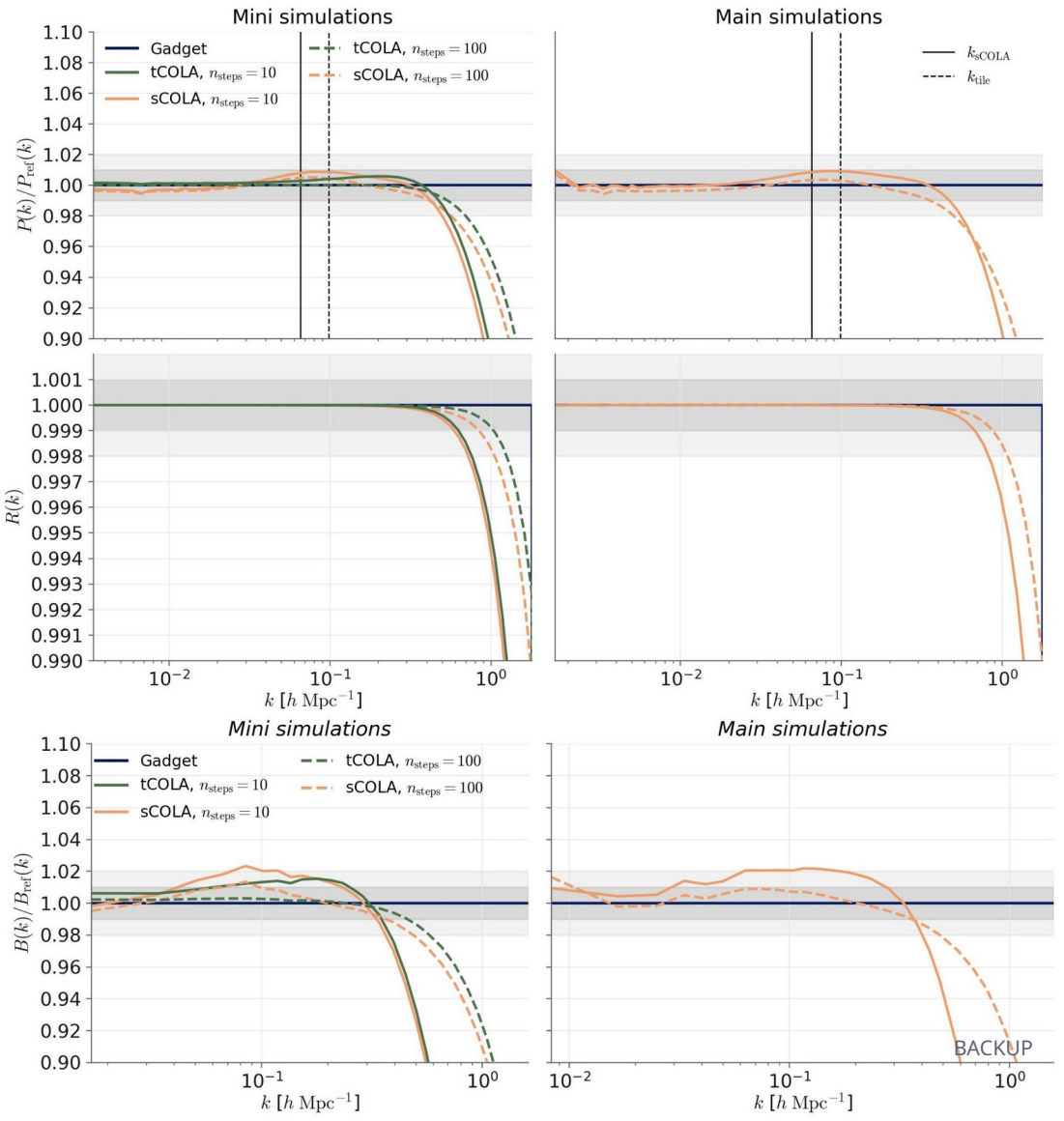
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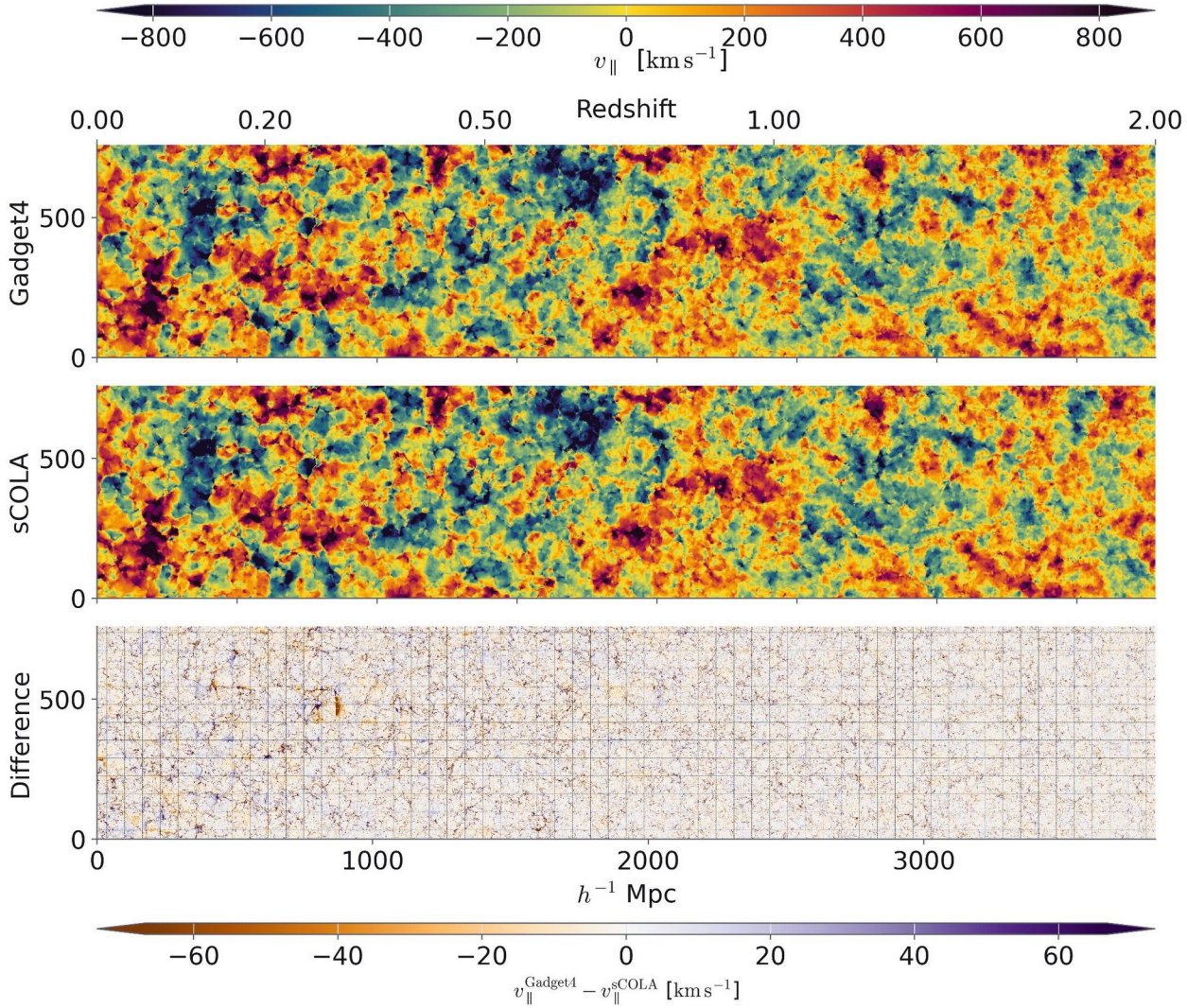
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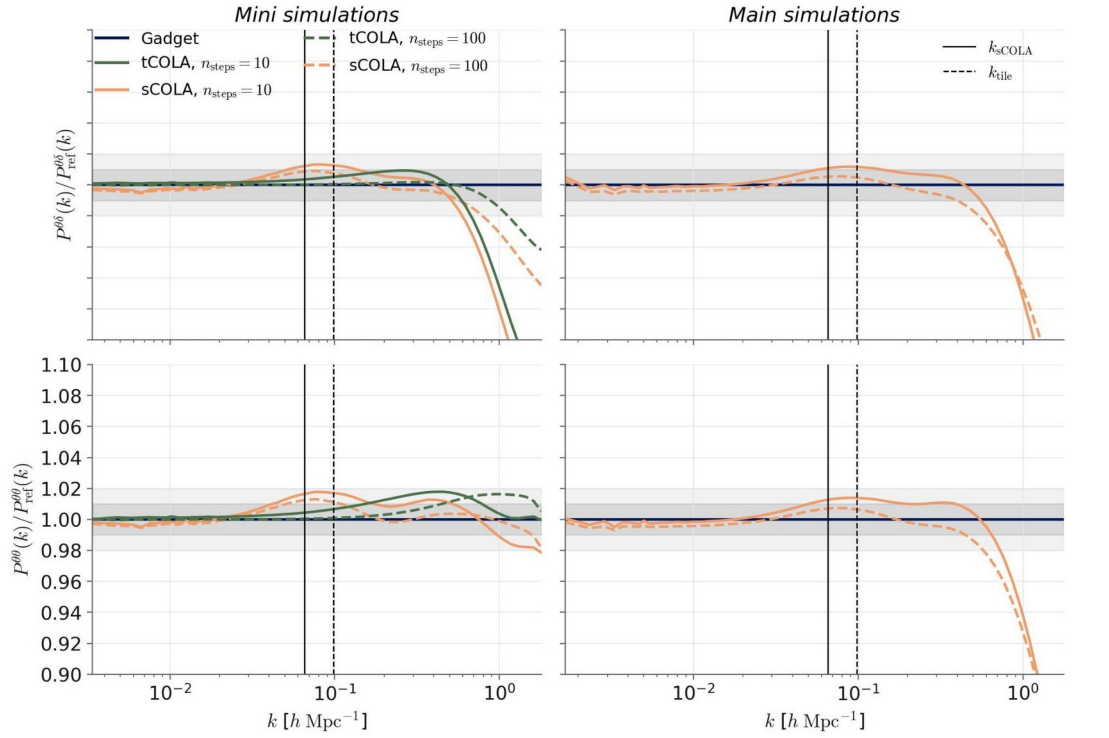
Dark matter density sCOLA vs Gadget4 lightcone



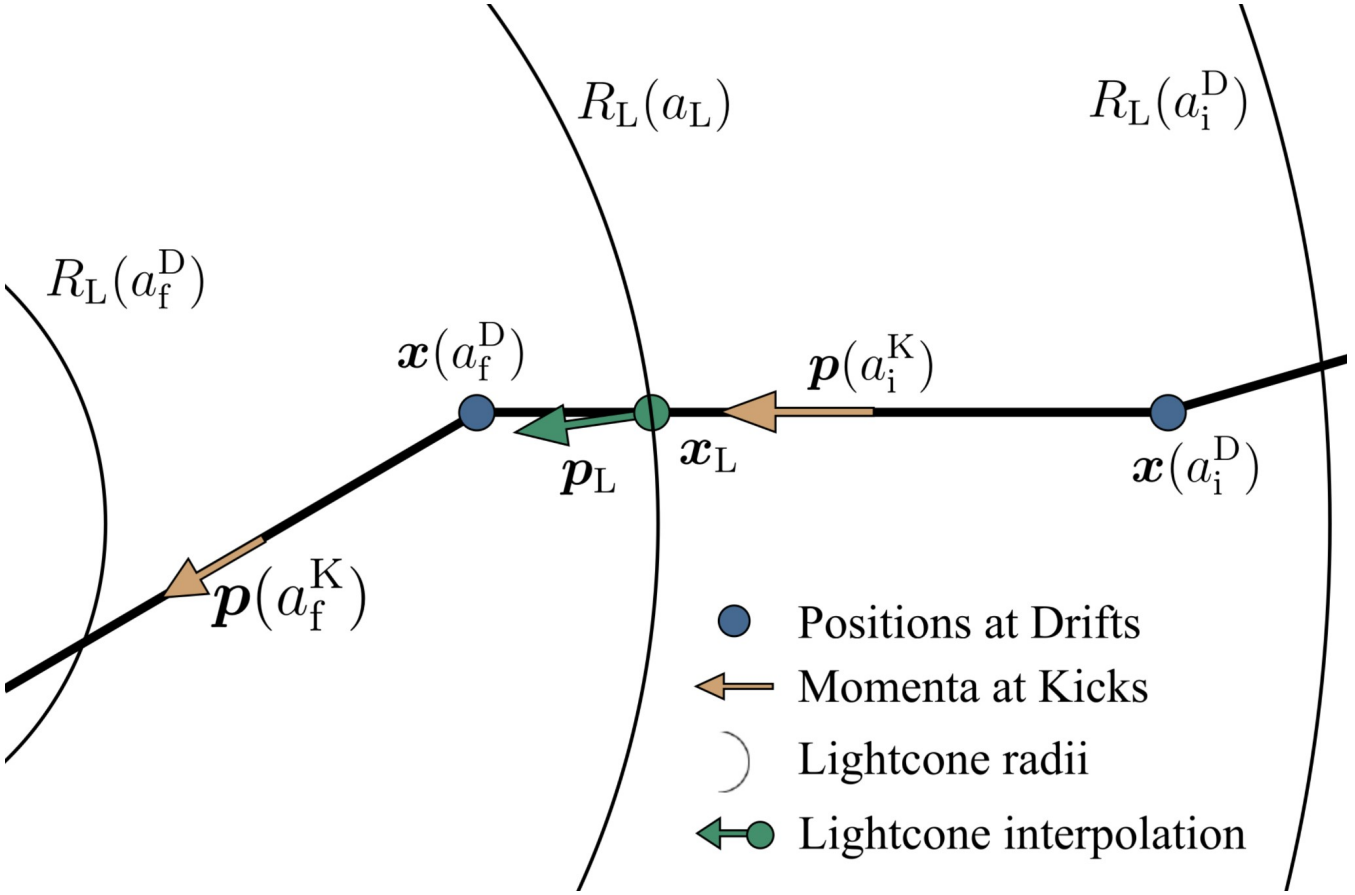


Dark matter velocity sCOLA vs Gadget4 lightcone

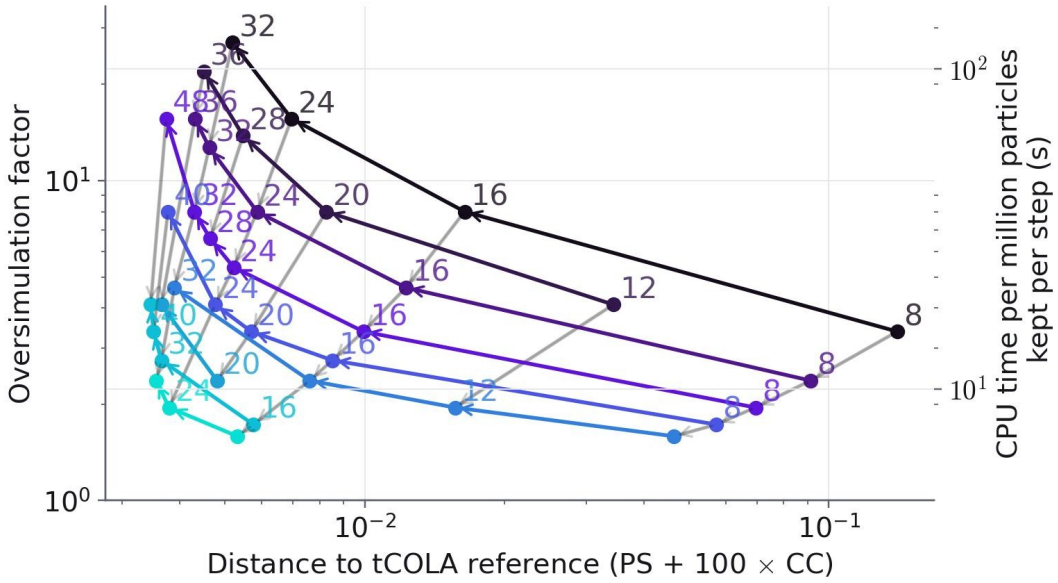


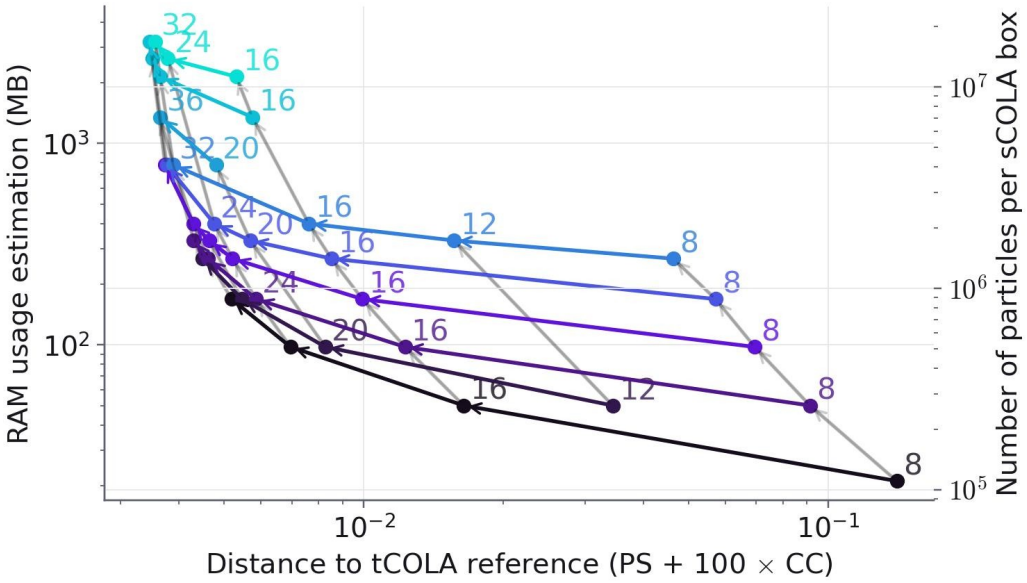


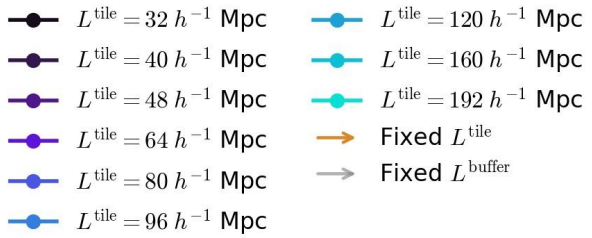
Lightcone interpolation scheme

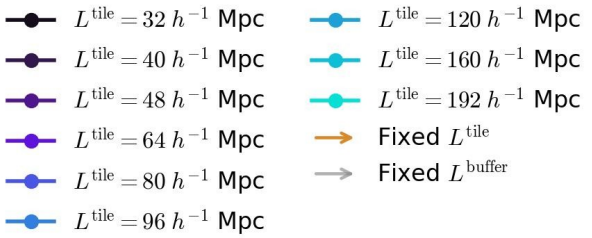


Optimal sCOLA configuration choice (at 1 Mpc/h resolution)

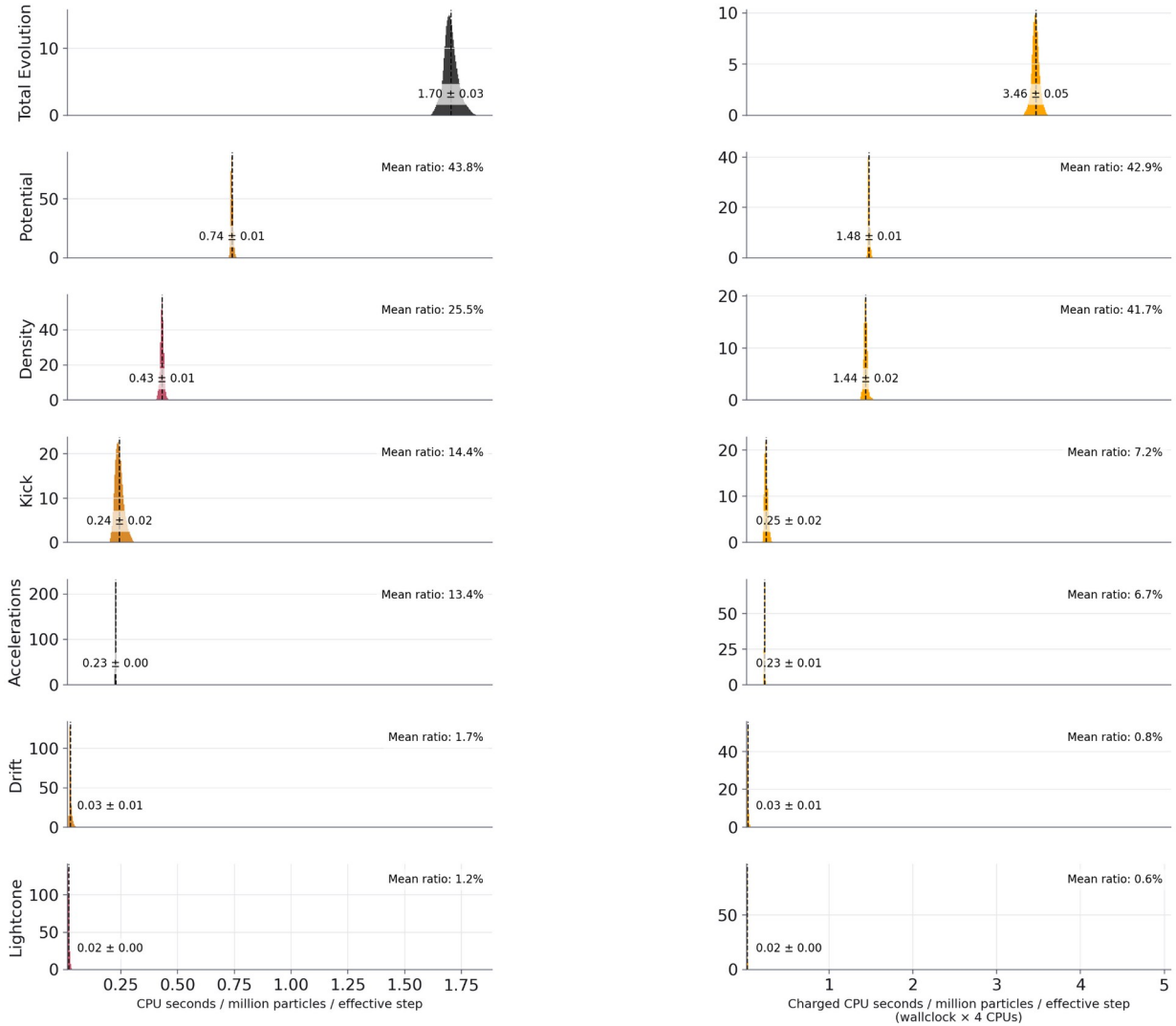


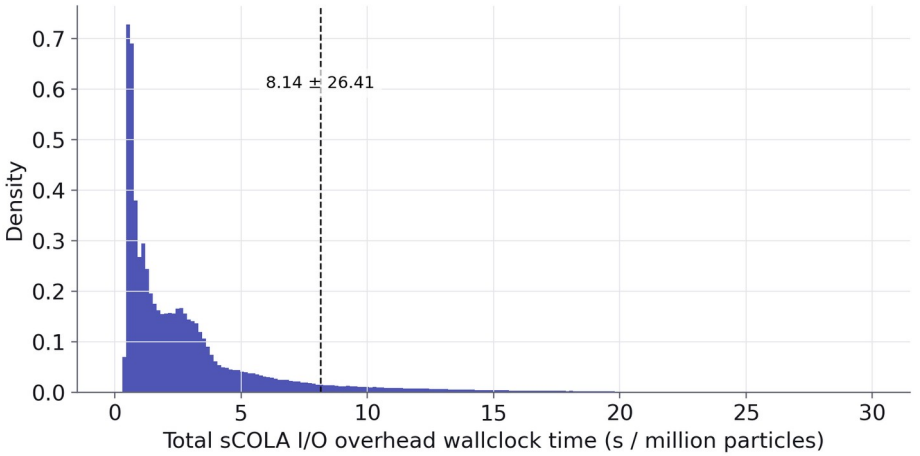


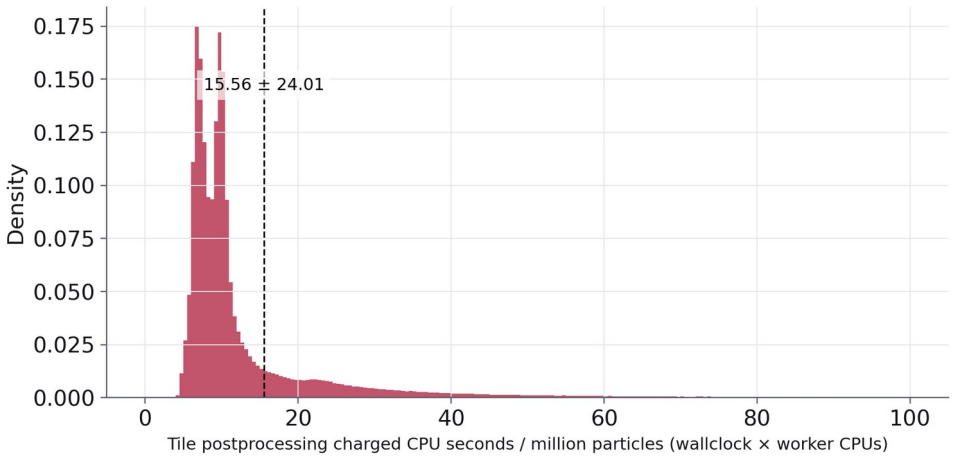




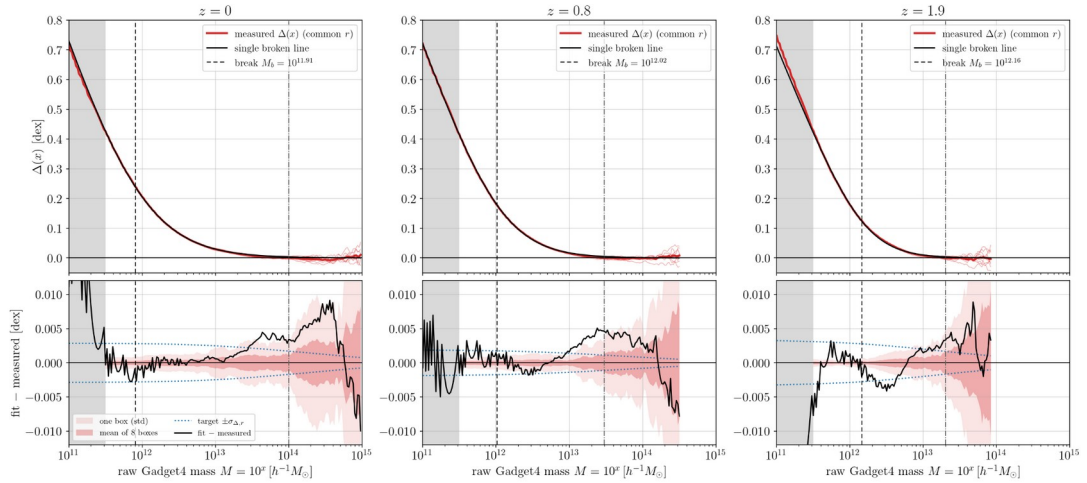
Measures of production computational costs of Silmarilli

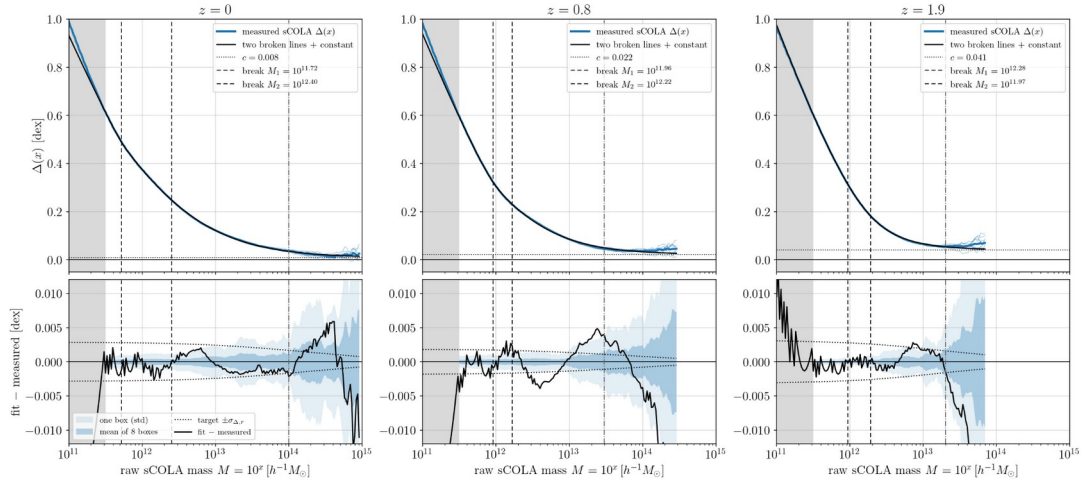






Preliminary halo mass remapping





Remapping of Gadget4 HMF due to discreteness effects at low masses onto r(z) * Tinker08, with a smoothly broken line (equivalent to a broken power law in masses). Parameters assumed to be linear in z.

$$\Delta(x,z) = \frac{s_0 + s_z z}{(p_0 + p_z z)\ln 10}\ln\left(1 + 10^{(p_0+p_z z)((x_0^b + x_z^b z) - x)}\right)$$

Remapping of sCOLA HMF onto the remapped Gadget4 with two smoothly broken lines (equivalent to two broken power laws in masses). Parameters assumed to be linear in z.

$$\Delta(x,z) = c_0 + c_z z + \sum_{k=1}^{2} \frac{s_k^0 + s_k^z z}{(p_k^0 + p_k^z z)\ln 10}\ln\left(1 + 10^{(p_k^0+p_k^z z)((x_k^{b,0} + x_k^{b,z} z) - x)}\right)$$

Can we find an approximation for N-body motion?

Scale factor

Position

Velocity

$$\mathbf{p} \equiv a \frac{\mathrm{d}\mathbf{x}}{\mathrm{d}\tau}$$

Kick

Conformal time

Newtonian gravitational potential

$$\frac{\mathrm{d}\mathbf{p}}{\mathrm{d}\tau} = -a \nabla_{\mathbf{x}} \Phi$$

Drift

Mean density of matter

Local overdensity

$$\Delta_{\mathbf{x}} \Phi \equiv 4\pi G a^2 \bar{\rho}_{\mathrm{m}} \delta$$

Forces

Can we find an approximation for N-body motion?

Velocity — Scale factor — Position

$$\mathbf{p} \equiv a \frac{\mathrm{d}\mathbf{x}}{\mathrm{d}\tau}$$

Conformal time — Newtonian gravitational potential

$$\frac{\mathrm{d}\mathbf{p}}{\mathrm{d}\tau} = -a \nabla_{\mathbf{x}} \Phi$$

Mean density of matter — Local overdensity

$$\Delta_{\mathbf{x}} \Phi \equiv 4\pi G a^2 \bar{\rho}_{\mathrm{m}} \delta$$

Linearise

$$\mathbf{x}_{1\mathrm{LPT}} = \mathbf{q} + D_1 \boldsymbol{\Psi}_1$$

Initial position — Growth factor (time dependent)

$$\boldsymbol{\Psi}_1 \equiv \nabla_{\mathbf{q}} \phi_1$$

Initial reduced gravitational potential

$$\Delta_{\mathbf{q}} \phi_1 \equiv \delta_{\mathrm{ini}}$$

Initial overdensity

Zel'dovich Y. B. (1970) · A&A 5, 84

Can we find an approximation for N-body motion?

Scale factor

Position

Velocity

$$\mathbf{p} \equiv a \frac{\mathrm{d}\mathbf{x}}{\mathrm{d}\tau}$$

Conformal time

Newtonian gravitational potential

$$\frac{\mathrm{d}\mathbf{p}}{\mathrm{d}\tau} = -a \nabla_{\mathbf{x}} \Phi$$

Mean density of matter

Local overdensity

$$\Delta_{\mathbf{x}} \Phi \equiv 4\pi G a^2 \bar{\rho}_{\mathrm{m}} \delta$$

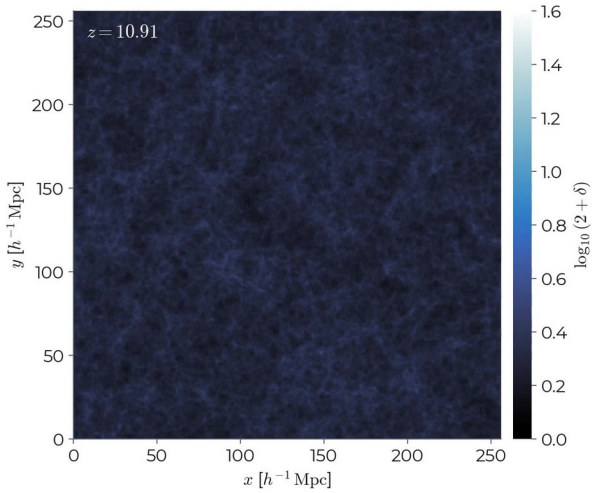
2^{nd} order

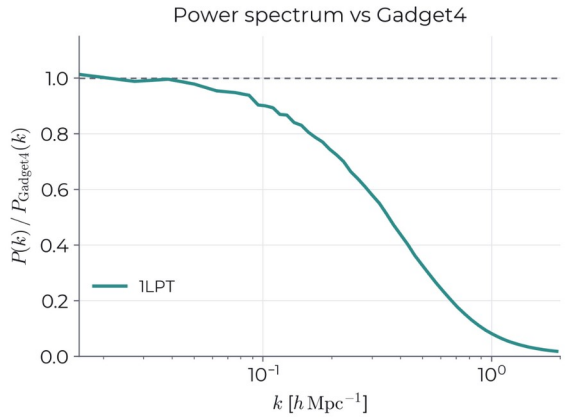
$$\mathbf{x}_{\mathrm{2LPT}} = \mathbf{q} + D_1 \boldsymbol{\Psi}_1 + D_2 \boldsymbol{\Psi}_2$$

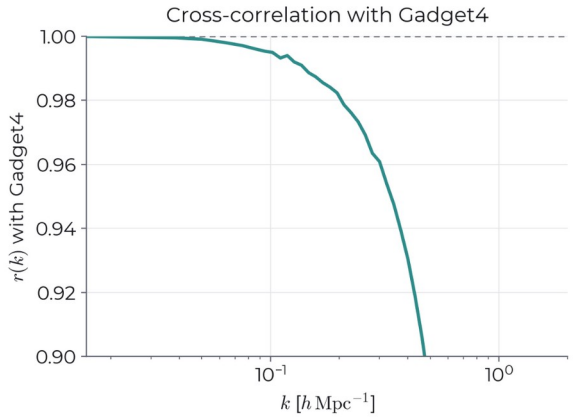
Bouchet F. R. et al. (1995) · A&A296, 575 · arXiv:astro-ph/9406013

Is Lagrangian Perturbation Theory (LPT) good enough?

1LPT

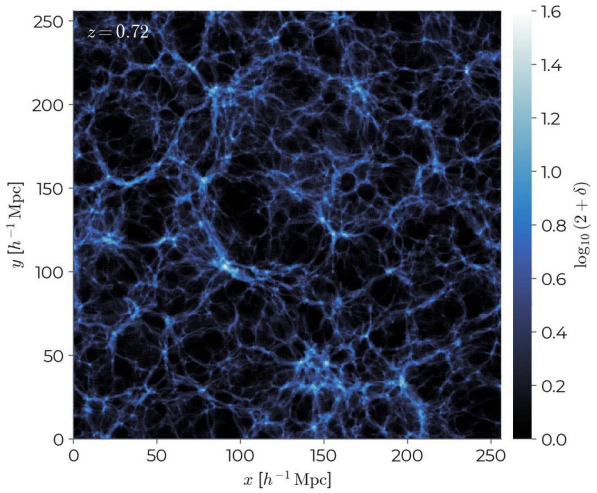


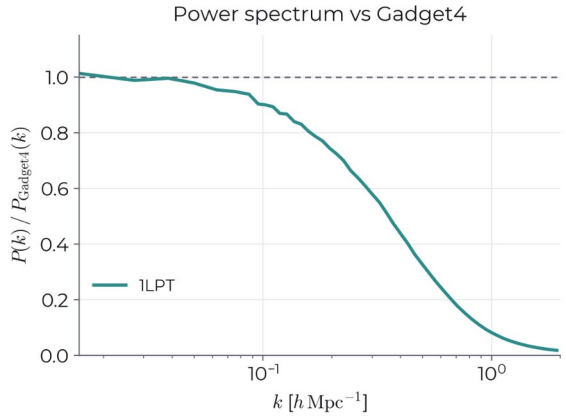


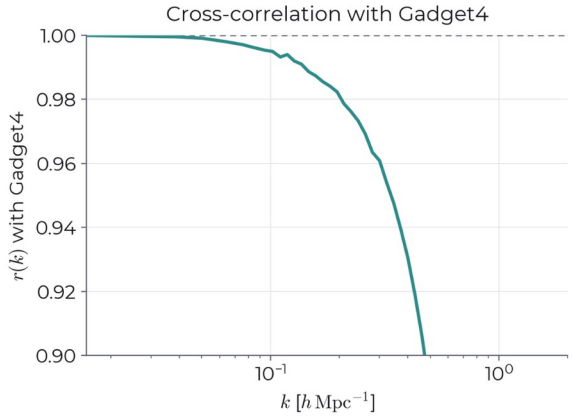


Is Lagrangian Perturbation Theory (LPT) good enough?

1LPT

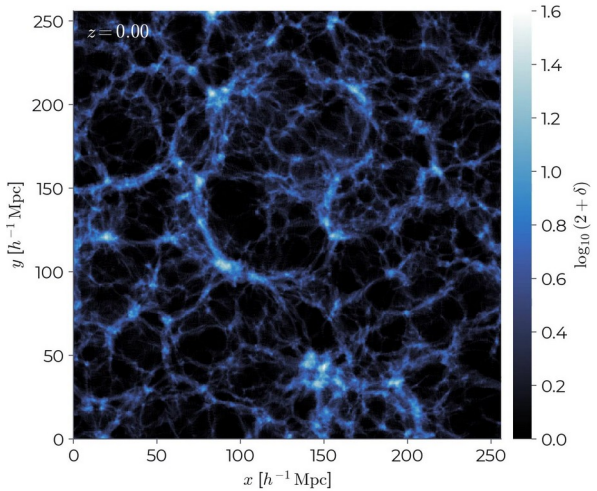


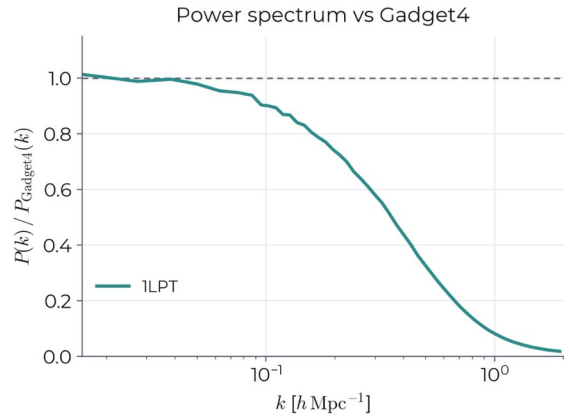


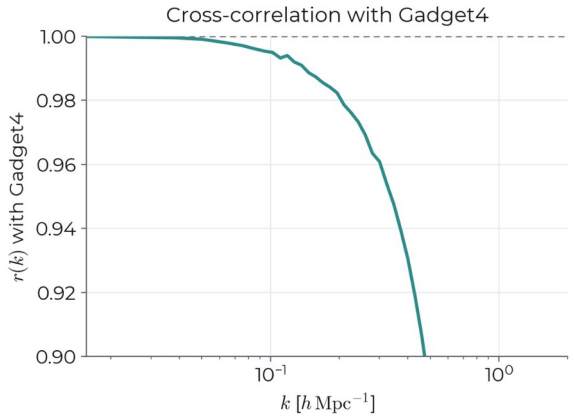


Is Lagrangian Perturbation Theory (LPT) good enough?

1LPT

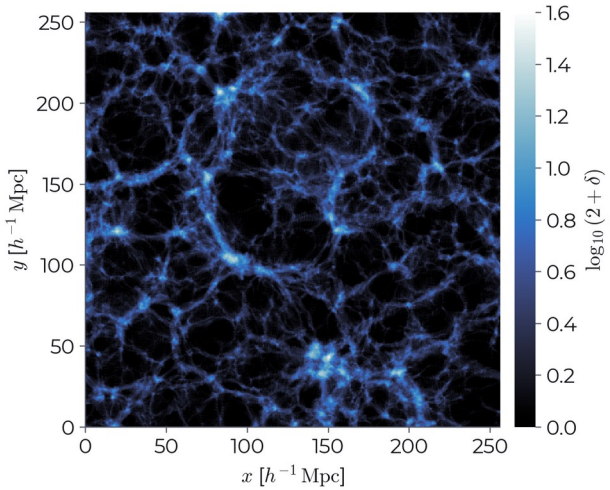




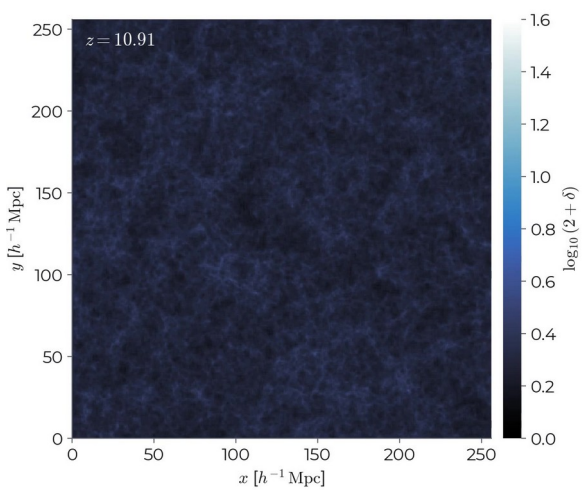


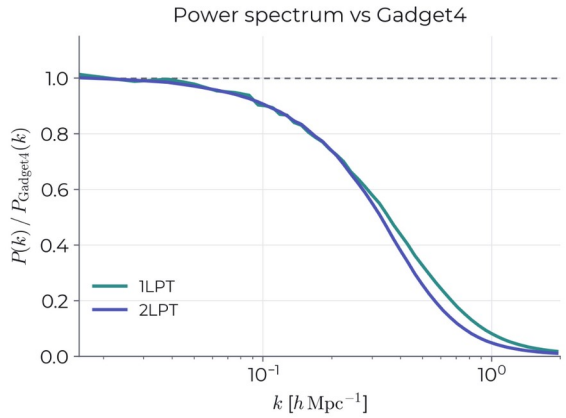
Is Lagrangian Perturbation Theory (LPT) good enough?

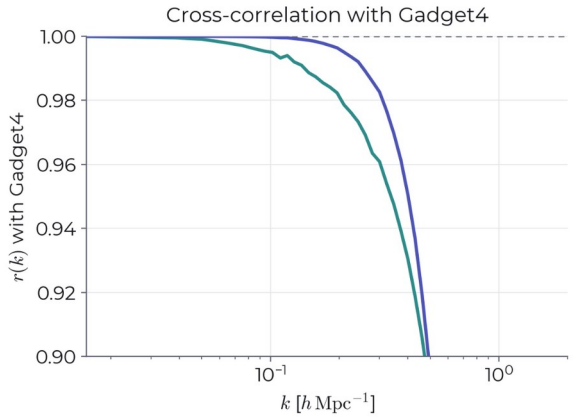
1LPT



2LPT

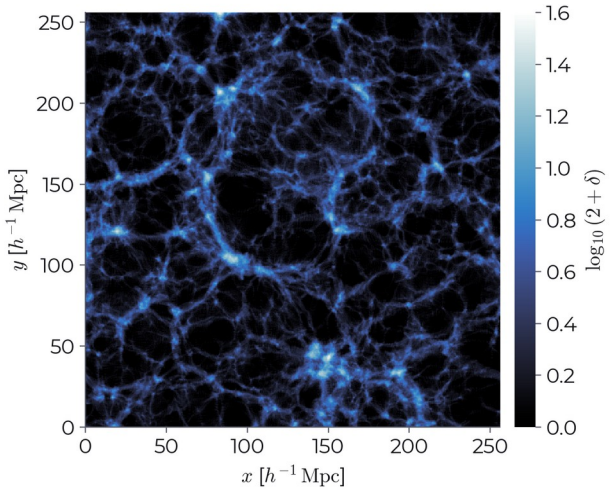




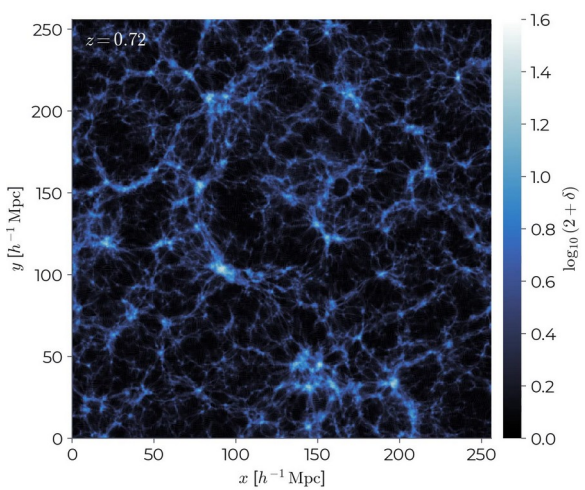


Is Lagrangian Perturbation Theory (LPT) good enough?

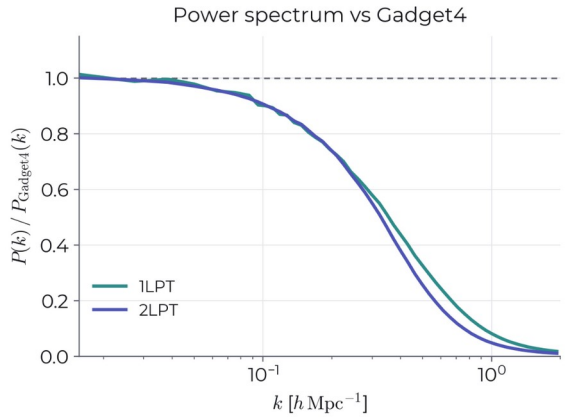
1LPT



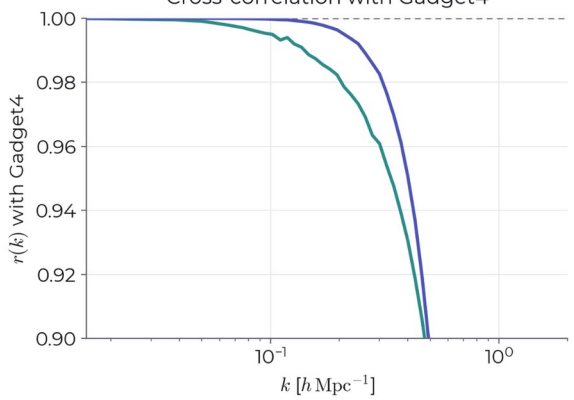
2LPT



Power spectrum vs Gadget4

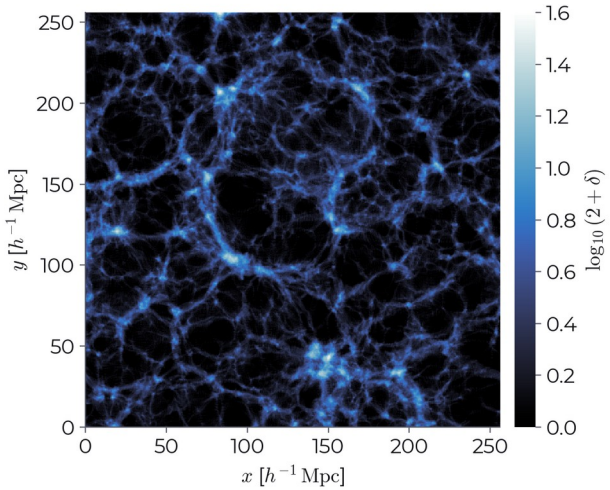


Cross-correlation with Gadget4

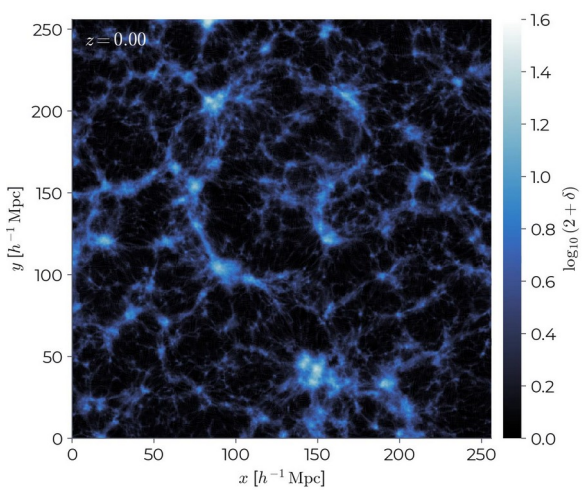


Is Lagrangian Perturbation Theory (LPT) good enough?

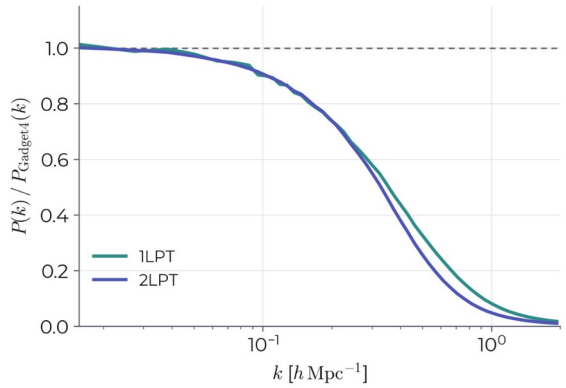
1LPT



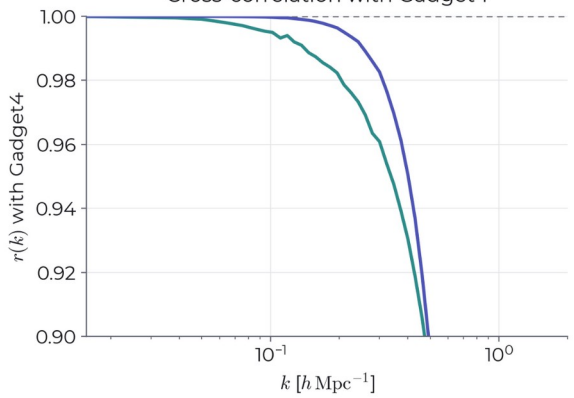
2LPT



Power spectrum vs Gadget4

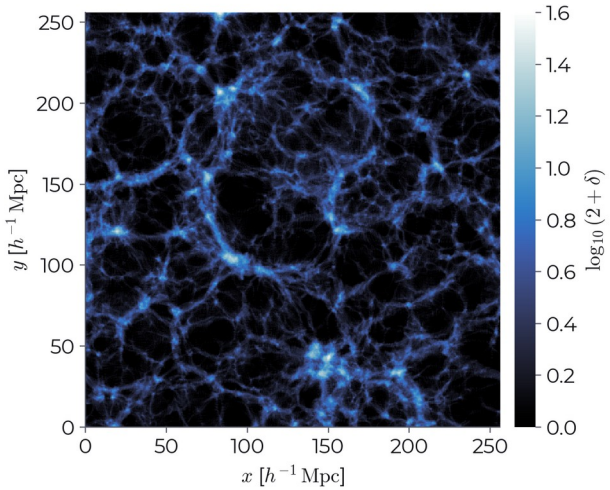


Cross-correlation with Gadget4

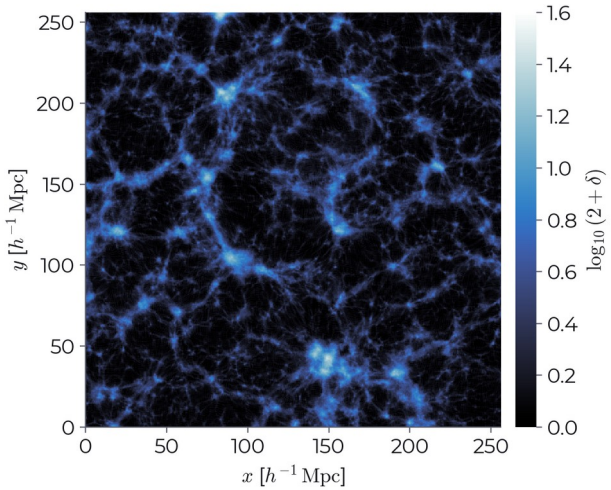


Is Lagrangian Perturbation Theory (LPT) good enough?

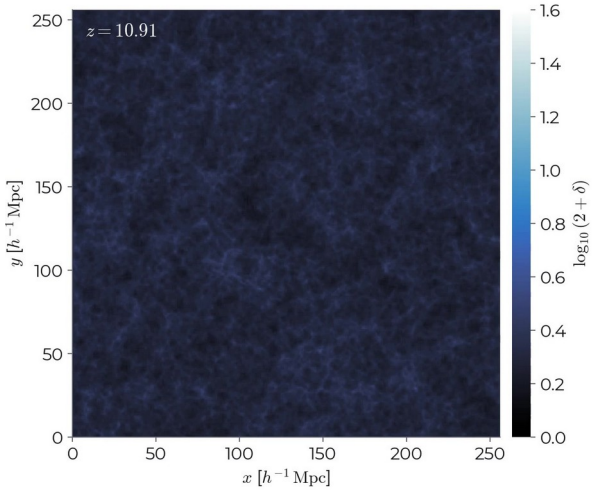
1LPT

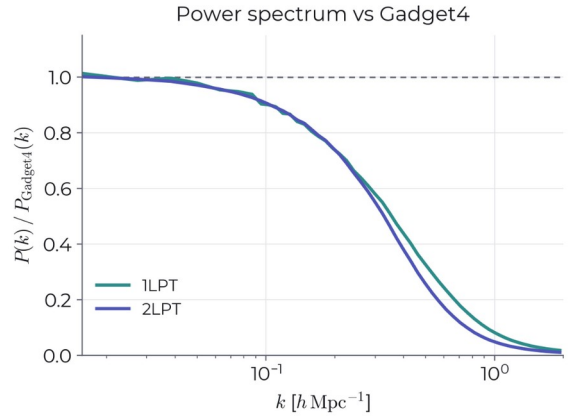


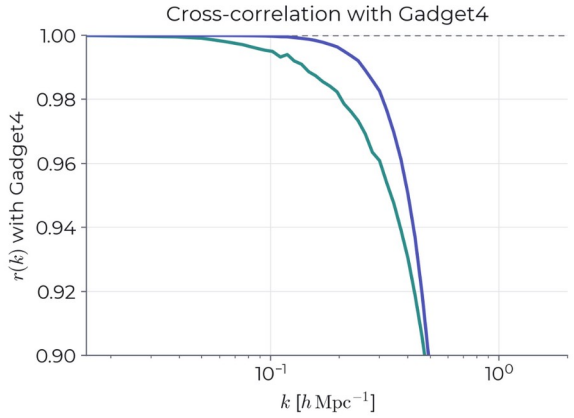
2LPT



N-body

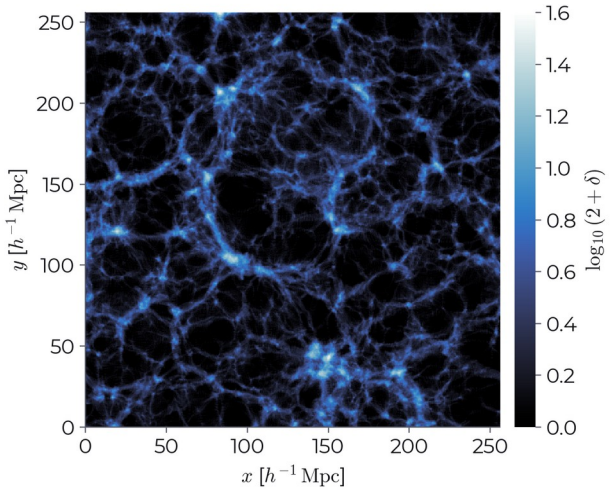




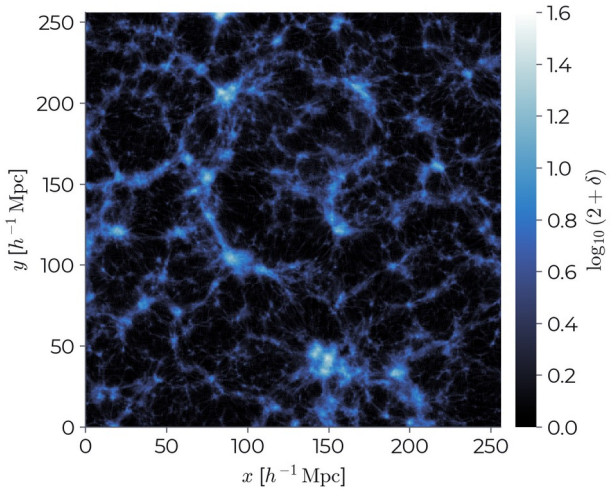


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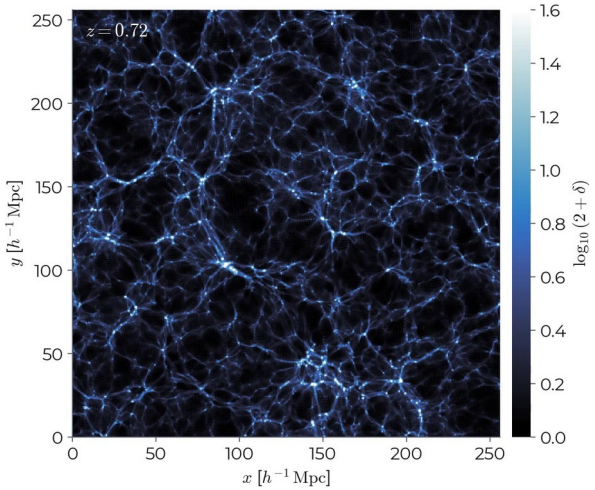
1LPT

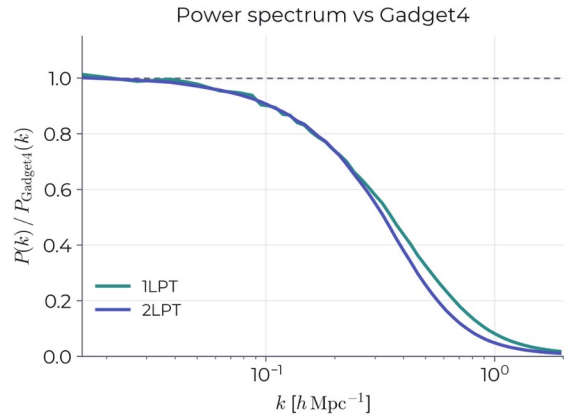


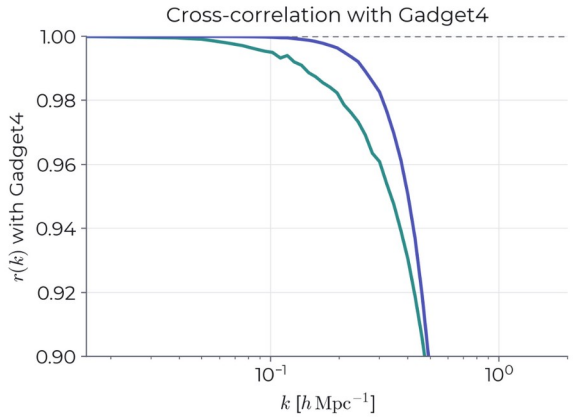
2LPT



N-body

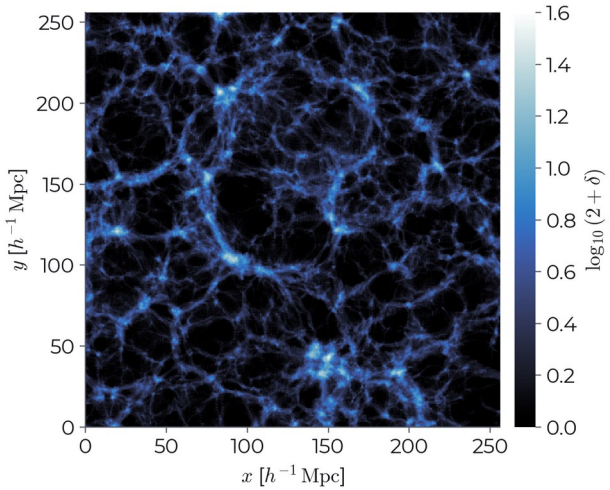




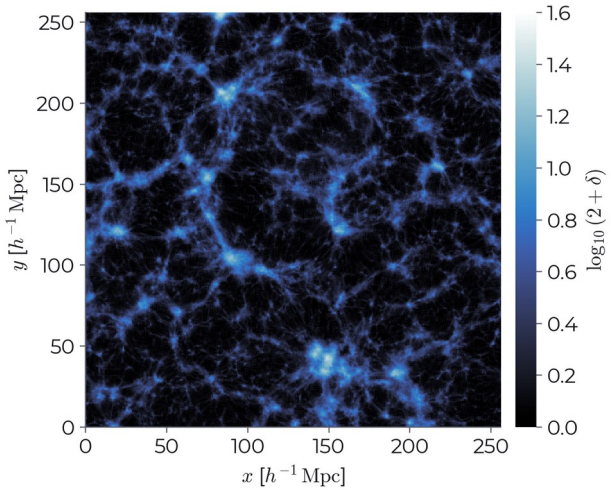


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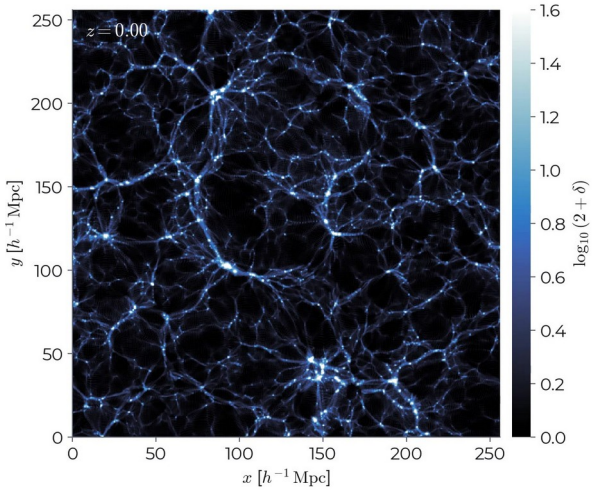
1LPT

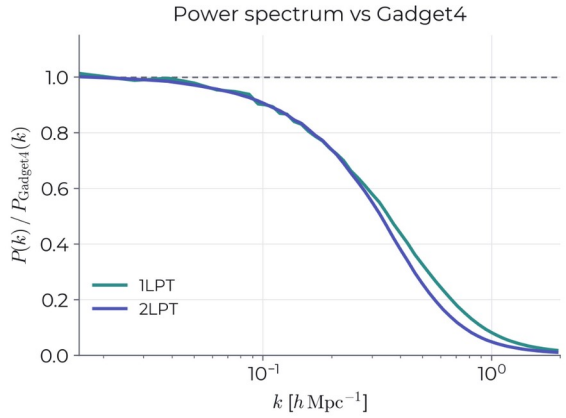


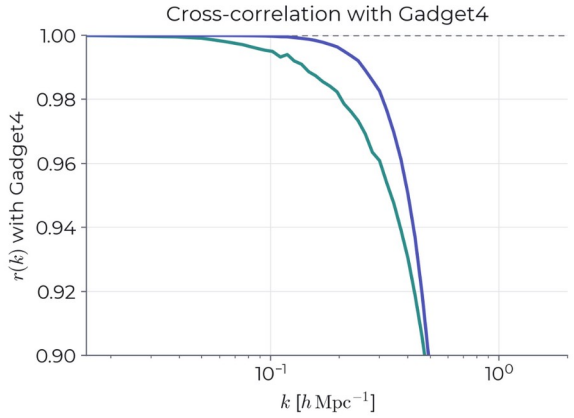
2LPT



N-body







Palette and type

Ink
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Space
#0B0D13

Amber
#D98A2B

Amber ink
#A8640F

Indigo
#4F55B5

Rose
#C2556B

Teal
#2E8C8A

Mute
#5E6270

Playfair Display

Titles 32 pt · sections 52 pt · takeaways italic 34 pt

Montserrat

Body 17 pt · columns 16 pt · captions italic 12 pt

IBM Plex Mono

Kickers 11 pt · references 8.5 pt · footer 8 pt

COLOUR MAPS



batlow Crameri · sequential, general use



arctic CMasher · density on dark slides



eclipse CMasher · echoes the amber accent



pride CMasher · cyclic, use sparingly