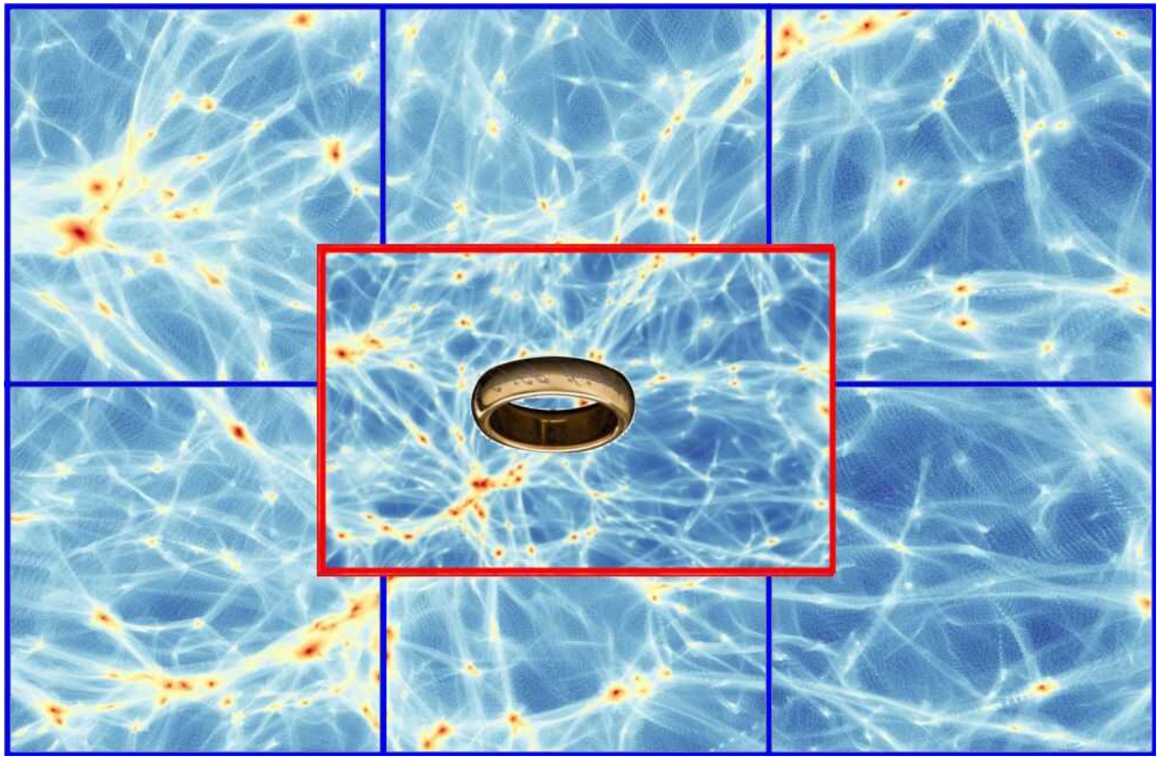
Bias and Clustering Calculations Optimised: Maximising discovery with galaxy surveys



By Sergio Contreras

With the collaboration of Raul Angulo,
Giovanni Aricò, Marcos Pellejero & Matteo Zennaro

08 - 04 - 2019

The group

Raul Angulo

Group leader

Matteo Zennaro

Postdoc

Giovanni Aricò

PhD. student

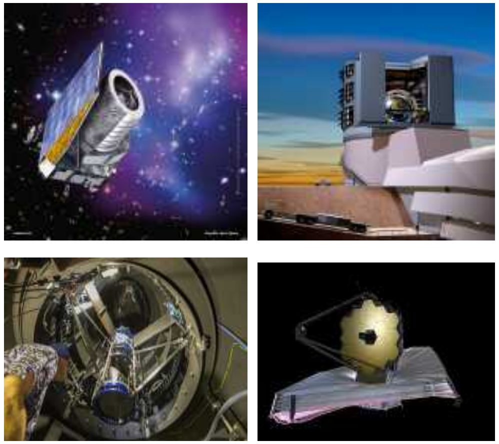
Marcos Pellejero

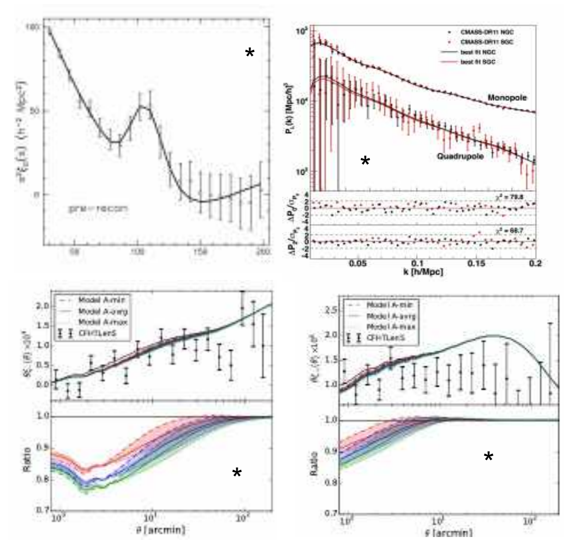
Postdoc

The working place

The project

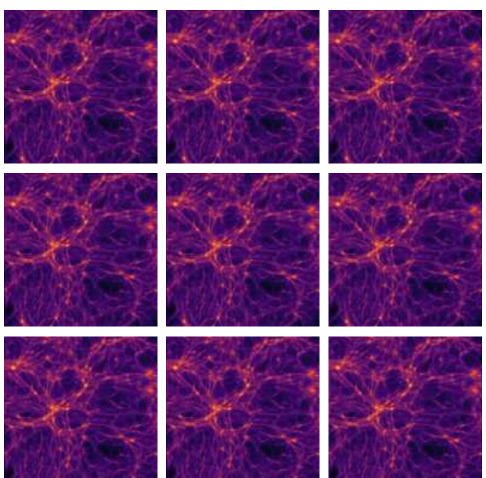
Galaxy surveys



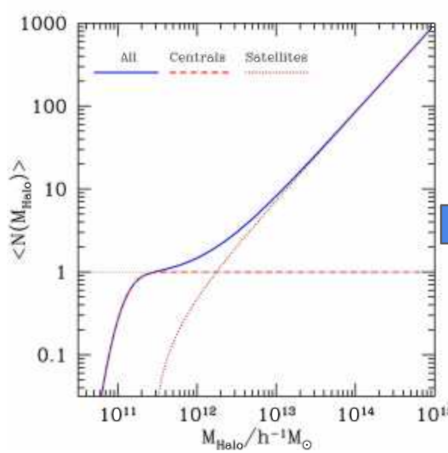


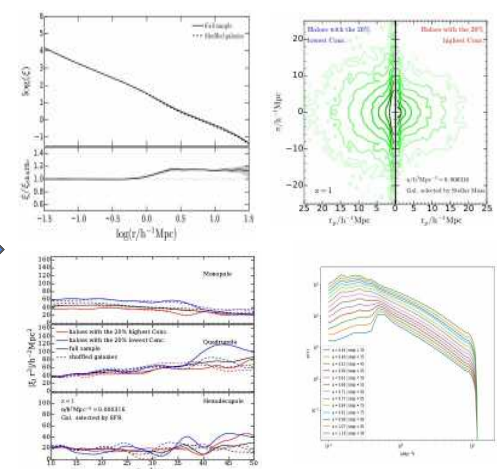
Non linear regime information

N-Body simulations



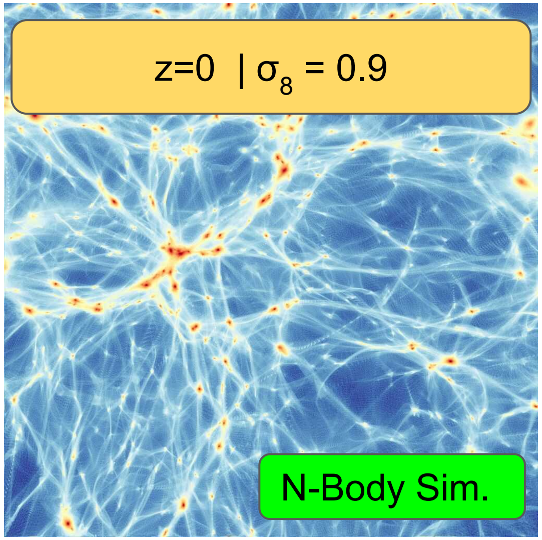
Galaxies
(eg. using HODs
or SHAMs)



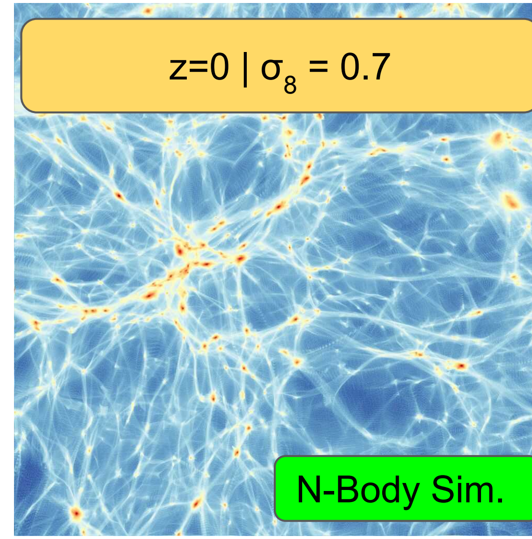


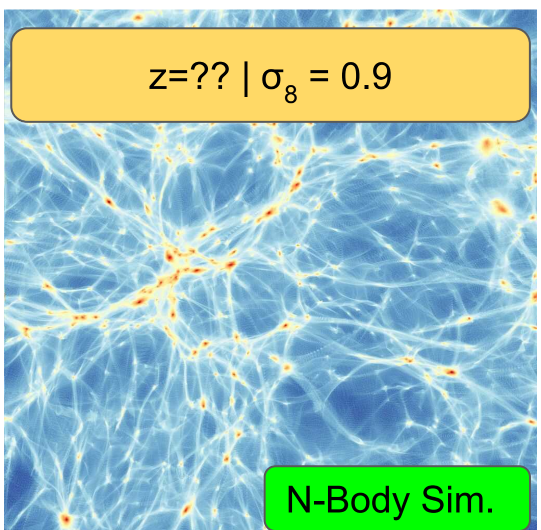
*Original plots from Anderson et al. (2013) & Schneider et. al. (2019)

The Scaling (basic summary)

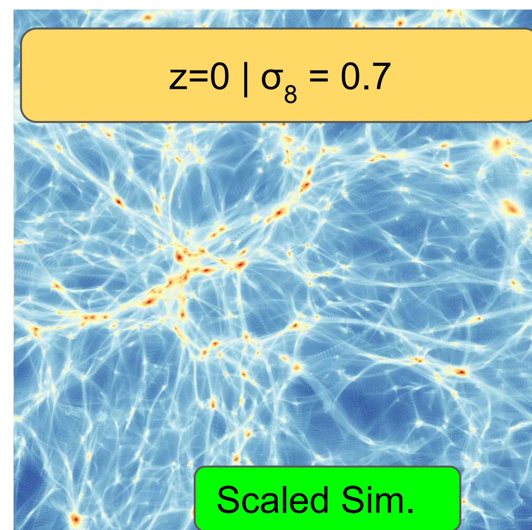


1) Find length and time scaling that minimize difference in linear fluctuations





2) Corr. large scale modes
3) Corr. nonlinear velocities
4) Corr. halo concentration



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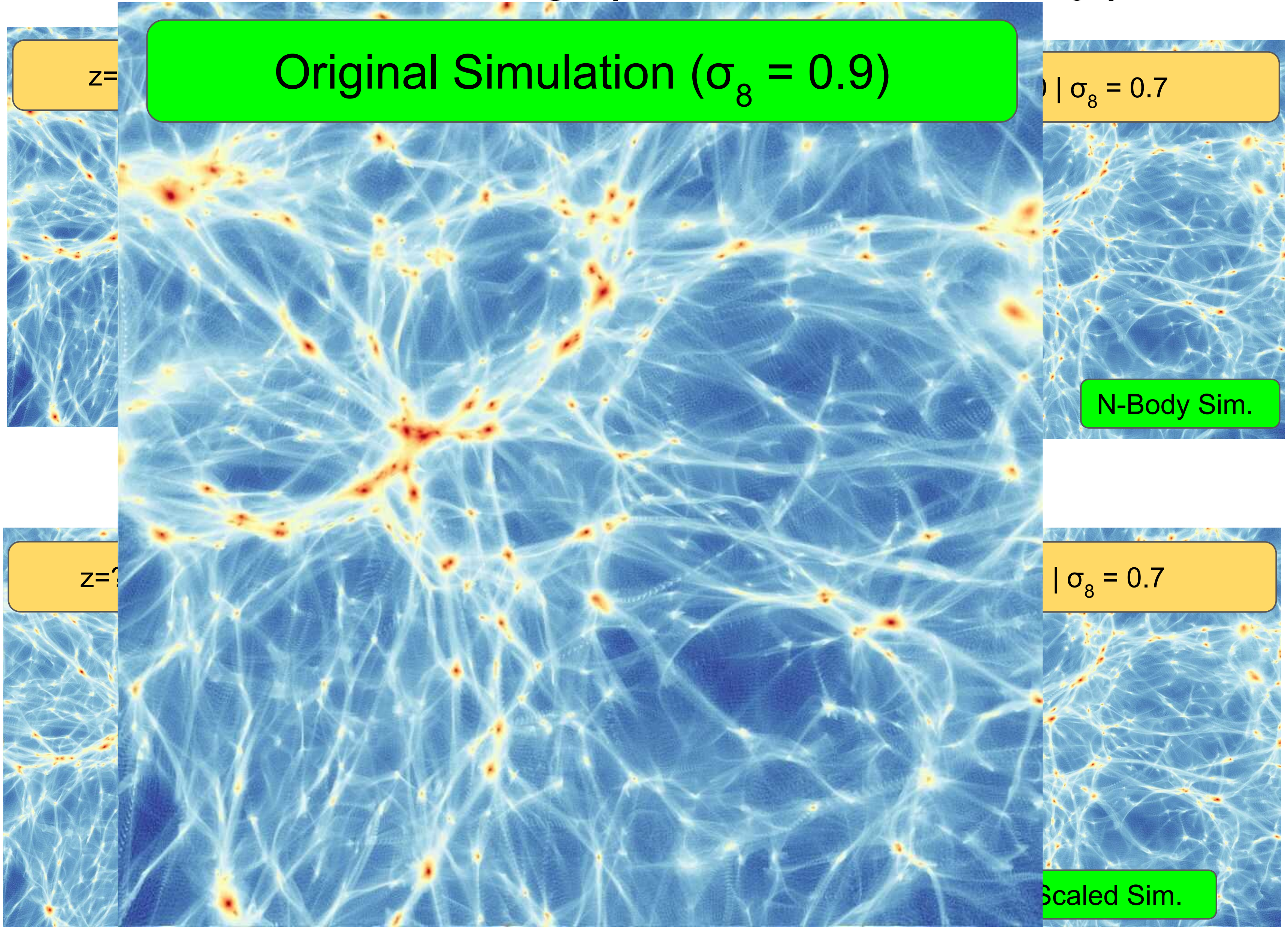

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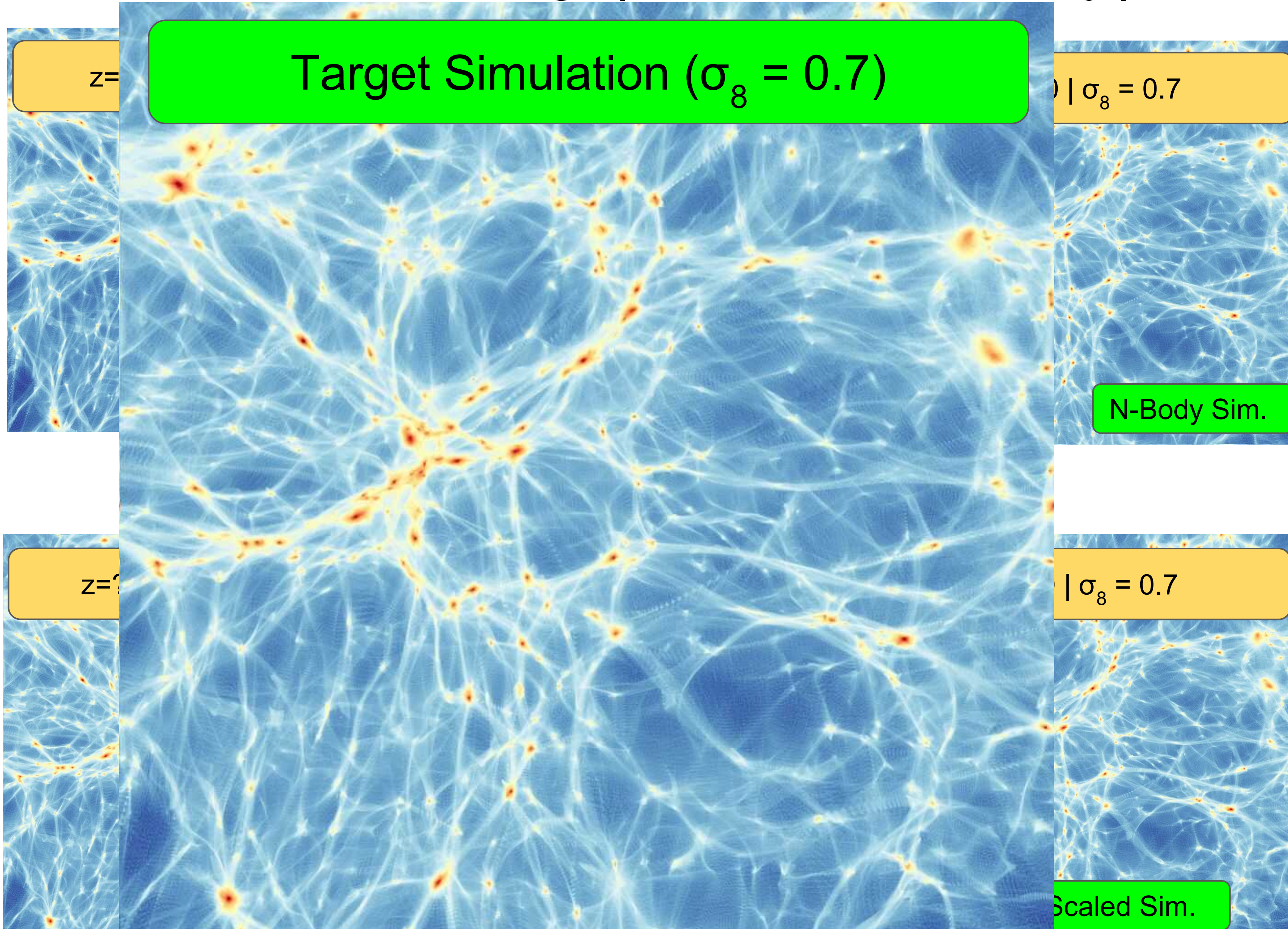
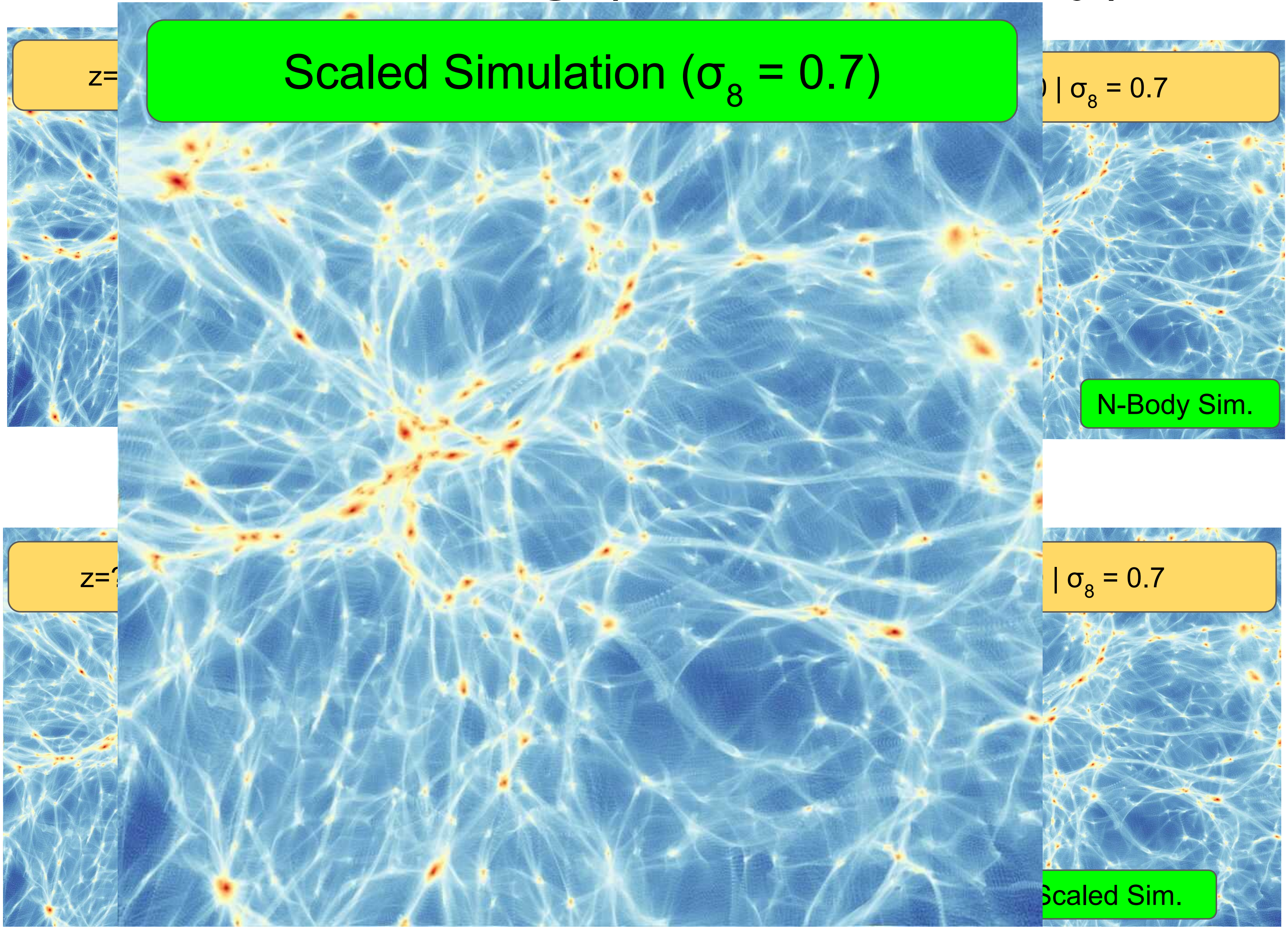
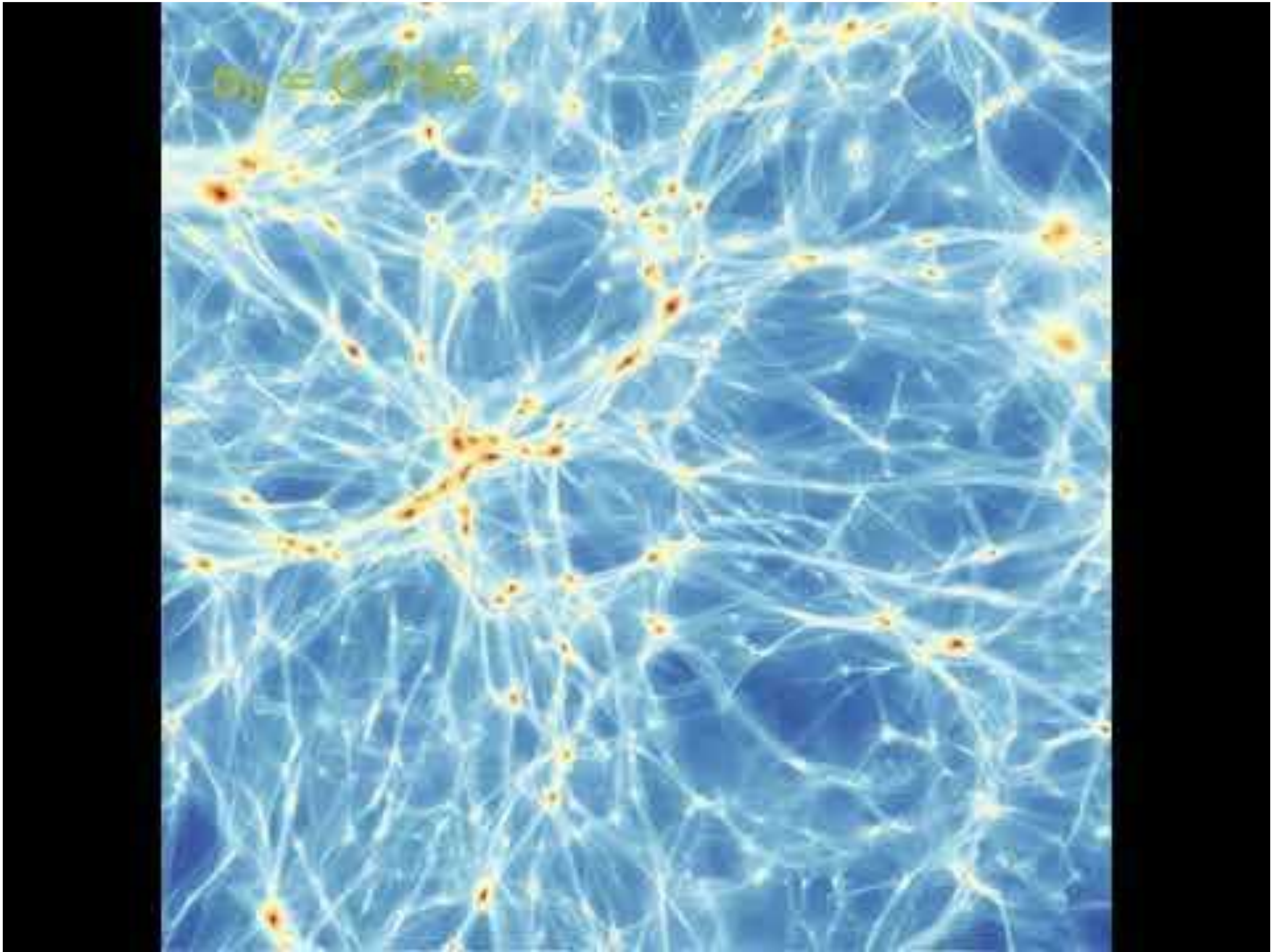


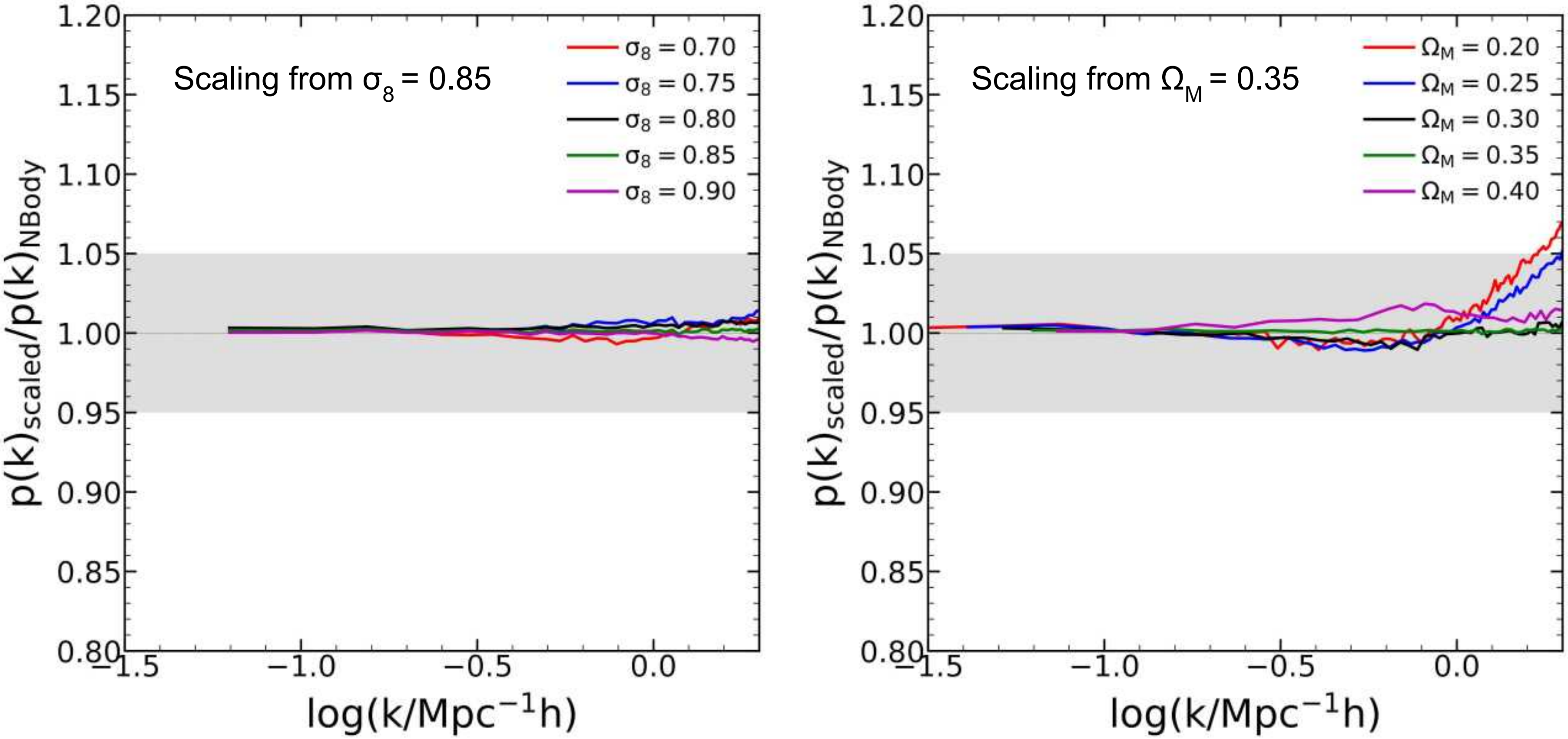
The Scaling (basic summary)



https://www.youtube.com/watch?time_continue=1&v=-YVEmTCE3tQ

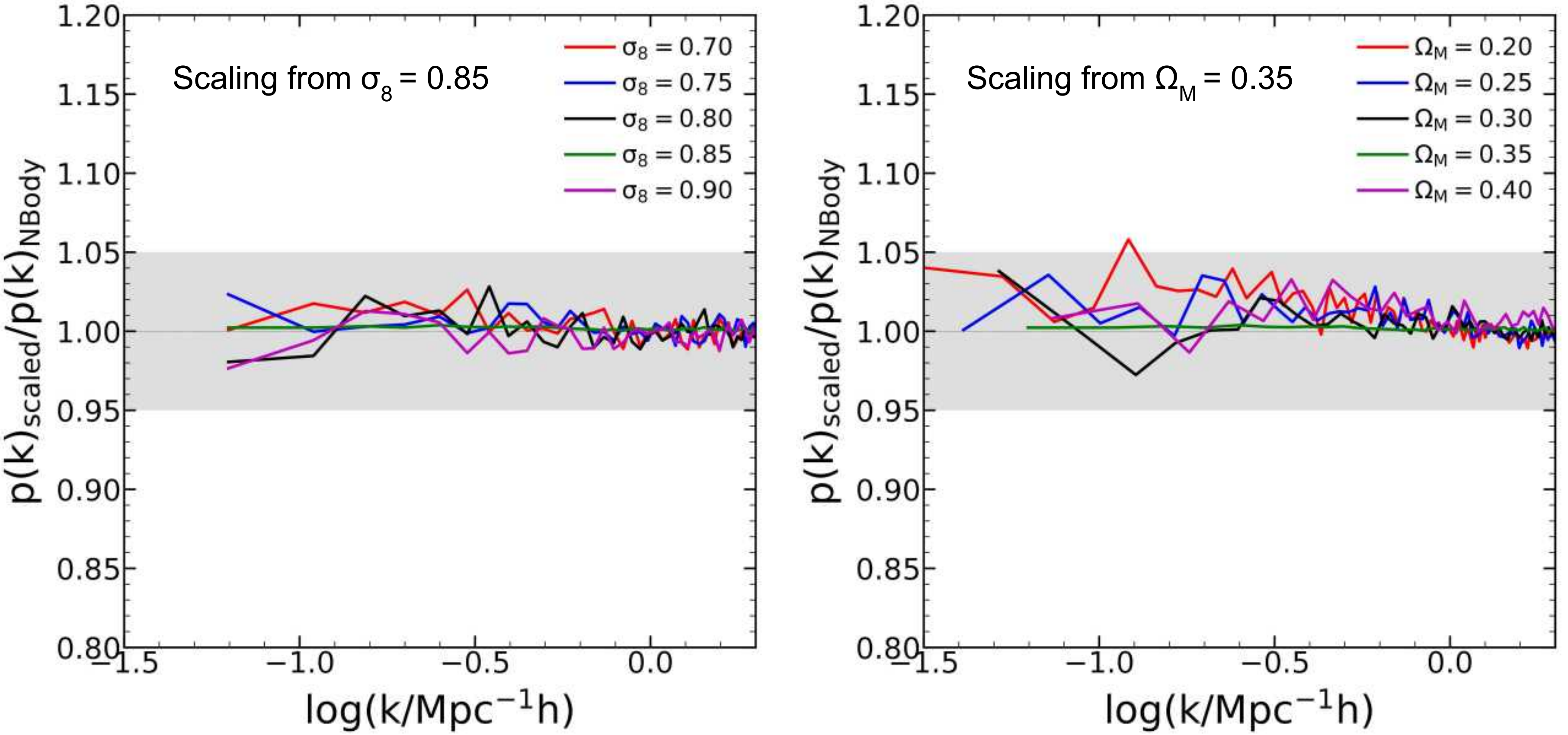


The Predictions



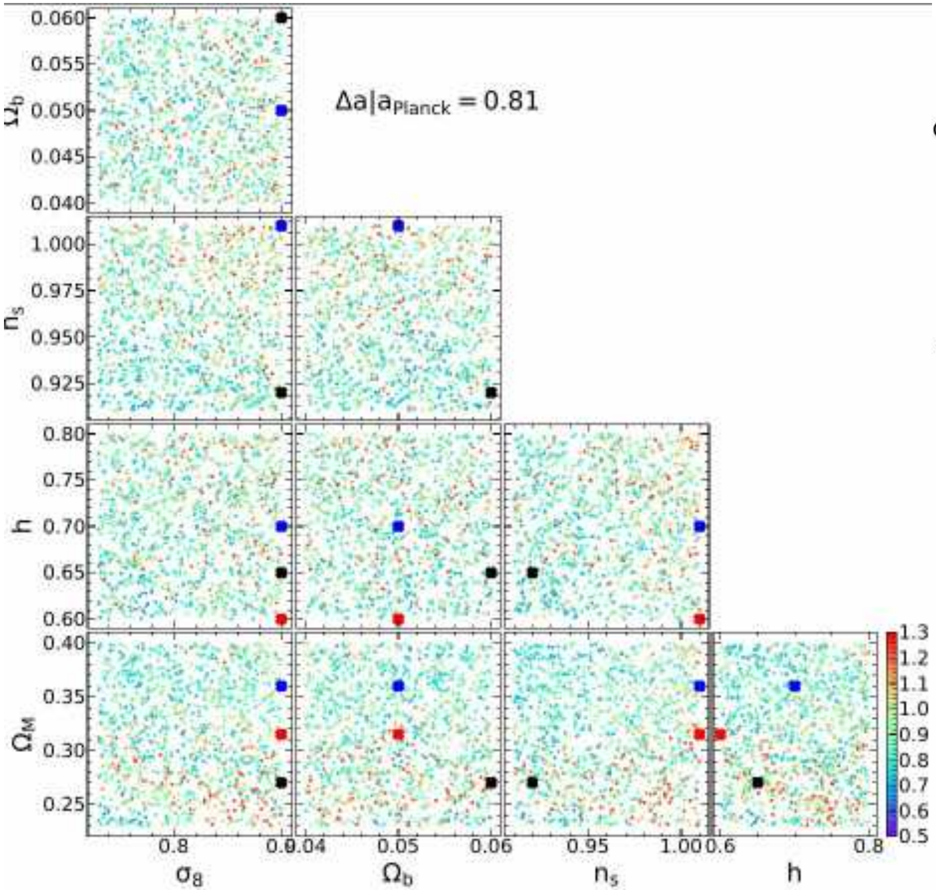
- Errors scaling dark matter particles always below 5% (k < 3 h/Mpc)
- Scaling h, M_v and Ω_b have similar or lower errors compared to scale by σ_8. n_s has a better performance than Ω_M.

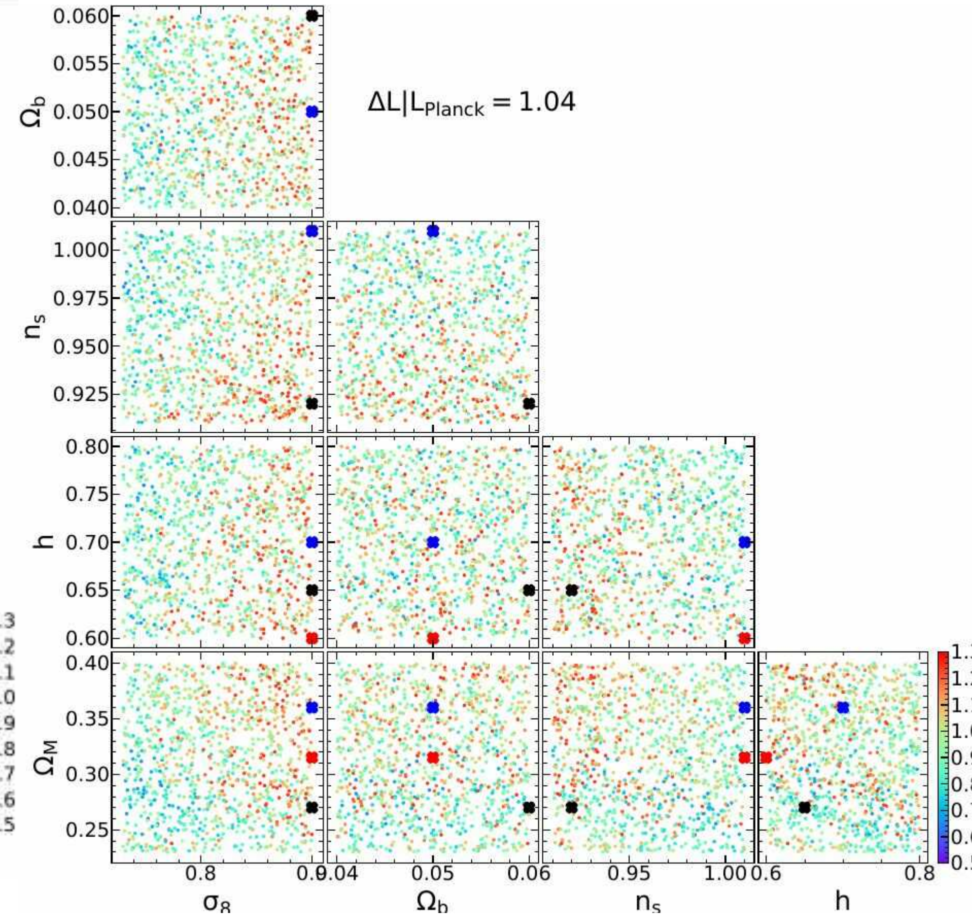
The Predictions



- Low error when scaling the haloes only.
- Scaling only haloes is faster and use less computational resources than scaling the dark matter particles
- Perfect for generating mocks with HOD using only 1 simulation….
  But that is **not** what we want.

The Cosmologies





The Cosmologies

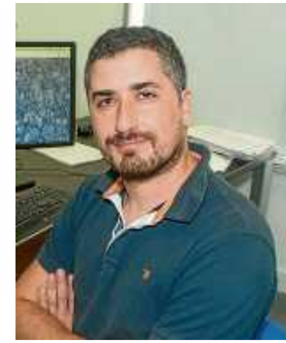
- We optimize the performance of the scaler on a parameter space 10σ larger than Planck proxies. These parameters will cover:
  - $\sigma_8 \in [0.73,0.9]$
  - $\Omega_M \in [0.23,0.4]$
  - $\Omega_b \in [0.04,0.06]$
  - $n_s \in [0.92,1.01]$
  - $h \in [0.6,0.8]$

- The number of simulations to run and their cosmology where chosen to minimize:
  - The error in the predicted p(k=1) of the scale simulations
  - The maximum time scale (a) at which the simulation need to be run
  - The maximum size at which the simulation will be scaled.

- We find that we optimally have to run 3 dark matter simulations with:
  - $\sigma_8 = 0.9$ $\Omega_M = 0.270$ $\Omega_b = 0.06$ $n_s = 0.92$ $h = 0.65$ (Vilya*)
  - $\sigma_8 = 0.9$ $\Omega_M = 0.315$ $\Omega_b = 0.05$ $n_s = 1.01$ $h = 0.60$ (Nenya*)
  - $\sigma_8 = 0.9$ $\Omega_M = 0.360$ $\Omega_b = 0.05$ $n_s = 1.01$ $h = 0.70$ (Narya*)

*Tentative names

The Tools



- L-Gadget3
  - Include a phase space halo finder algorithm
  - Compute FOF, subfinds & merger trees on the fly
  - Compute orphans
  - Compute & save other useful properties (eg. Vpeak, accretion mass, etc)
  - Save fraction of DM particles (as needed)

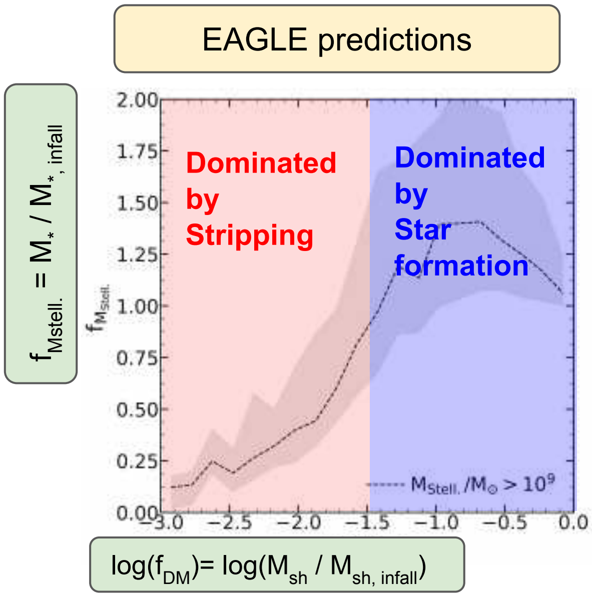
- Bacco
  - Python, cython & C cosmological tool package
  - Allow loading, scaling and analysing dark matter simulations
  - Include a series of additional tools that include (and are not limited) to:
    - Creating mocks (using SHAM, HODs and more!)
    - Analysing errors
    - Visualise simulations (and make movies)
    - Emulators and MCMC packages
    - All kind of analysis to the haloes, subhaloes, galaxies & dark matter particles of the simulations (eg. correlation function, power spectrum, multipoles, mass function, mass-concentration relation, etc)

- Others
  - Pair simulations

The Galaxies

~WIP

Mock Durham 2018



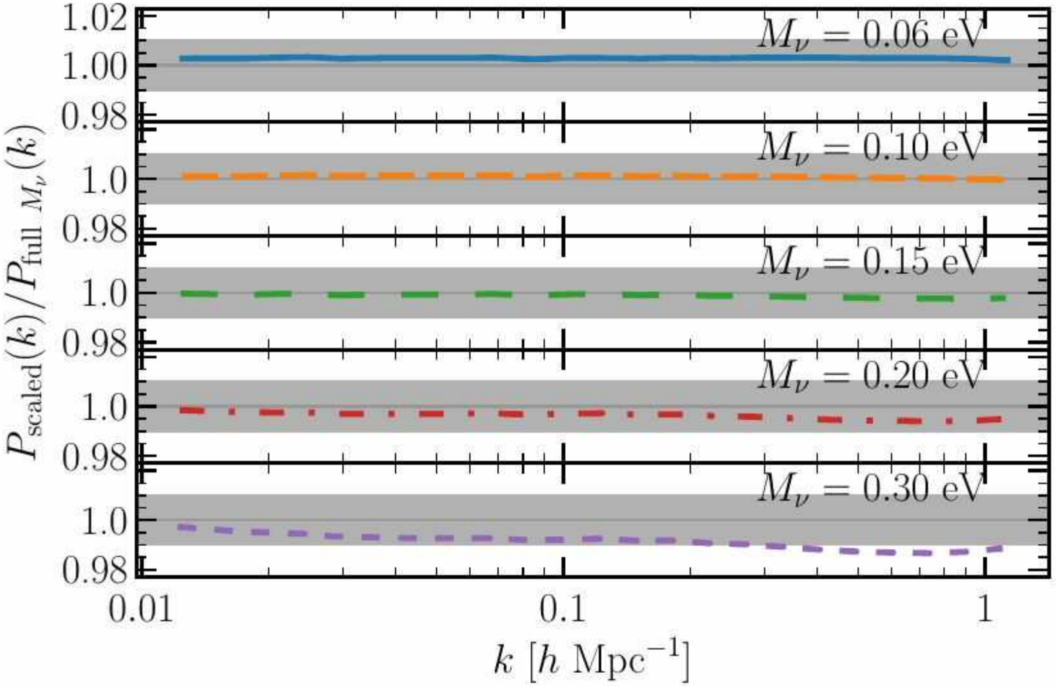
- Accretion model on SHAM
- SFR-SHAM mocks
- Automatic computation of stellar mass function, correlation functions, power spectrum, covariance matrix, multipoles, etc
- MCMC and emulator implementation to predict cosmological information from galaxy clustering.

The Neutrinos

Scaling with massive neutrinos:

- Minimize the difference in the **cold** matter linear amplitude
- Include **scale dependent** growth rate and growth factor
- The **large scale correction** preserves the correct scale dependence of the clustering

Ratio of P(k) of a ΛCDM scaled simulation and a simution actually run with neutrinos



Results:

- 1% accuracy on **power spectrum** up to k~1 h/Mpc
- Few % accuracy on **halo abundance**
- Same level of accuracy on **SHAM galaxies** correlation function as in ΛCDM

Original slide from M. Zennaro

~WIP

The Baryons

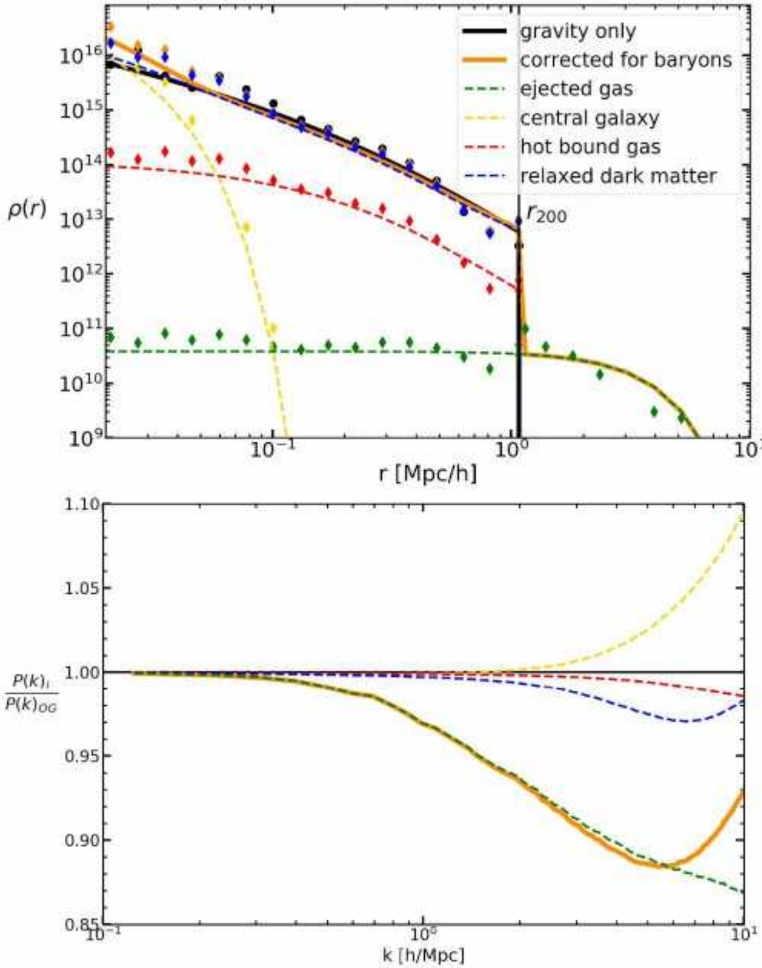
Adding baryon physics into only-gravity simulations

Why?

- ~10-20% effect on the matter Power Spectrum at k~10 h/Mpc
- Accurate predictions for Weak Lensing surveys
- Joint constraints on cosmology and baryon physics

How?

- A posteriori halo by halo displacements of particles exploiting analytical halo density profiles
- Cosmology rescaling + baryon correction model to measure matter Power Spectrum and shear angular Power Spectrum
- Fisher / MCMC analysis to explore degenerations between cosmological and baryonic parameters



Original slide from G. Arico

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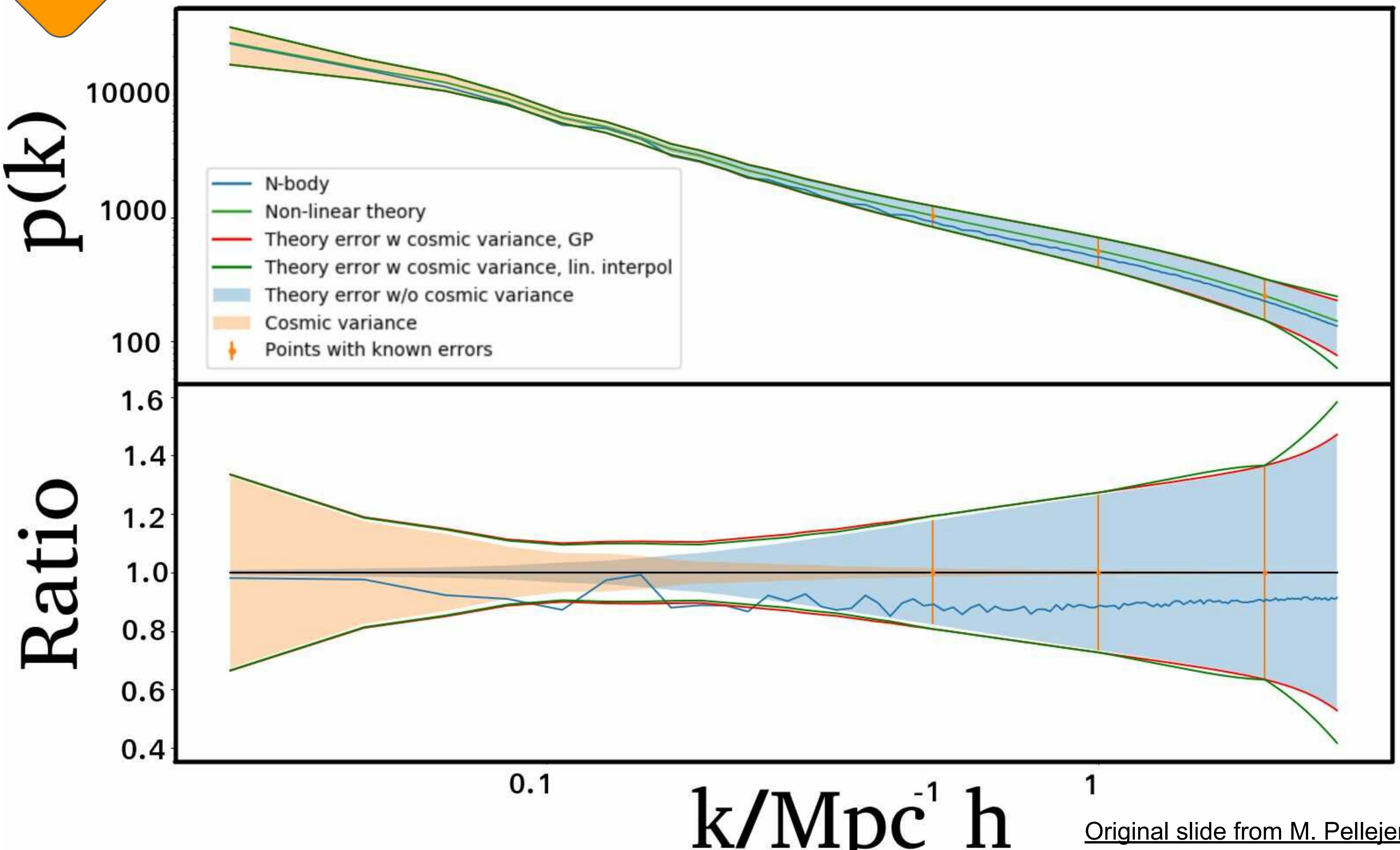
The Errors



Original slide from M. Pellejero

Take away message

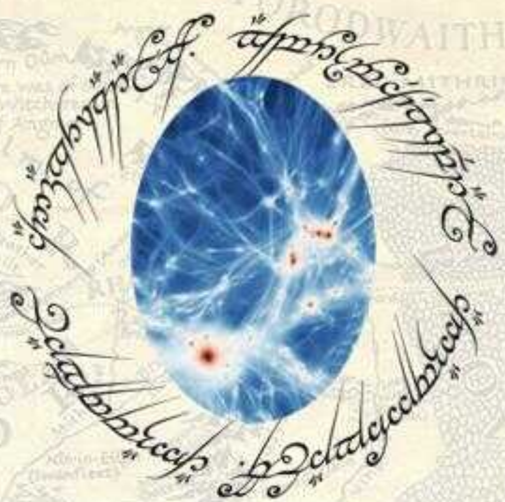
- The scaling technique can be used to constrain cosmology from observations using only a reduce number of simulations.

- By running less simulations, we can do them largers and with higher resolution.

- Higher resolution simulations allowed us to use more sophisticated techniques to populate haloes with galaxies

- Errors in the scaling are much lower than other sources of errors (like HODs or SHAMs)

- Always remember Bacco’s moto:



One Simulation to fit them all,
One Simulation to scale them,
One code to rule them all,
and with Python analyse them.

Import Bacco