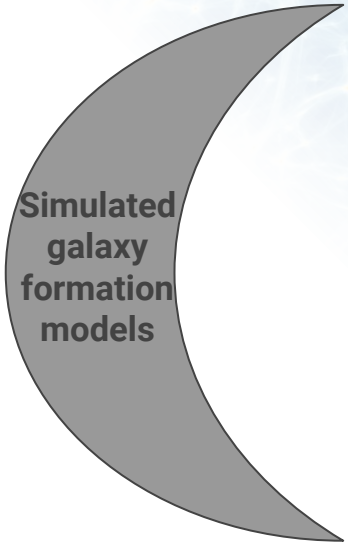
How to build an agnostic model from an N-body simulation

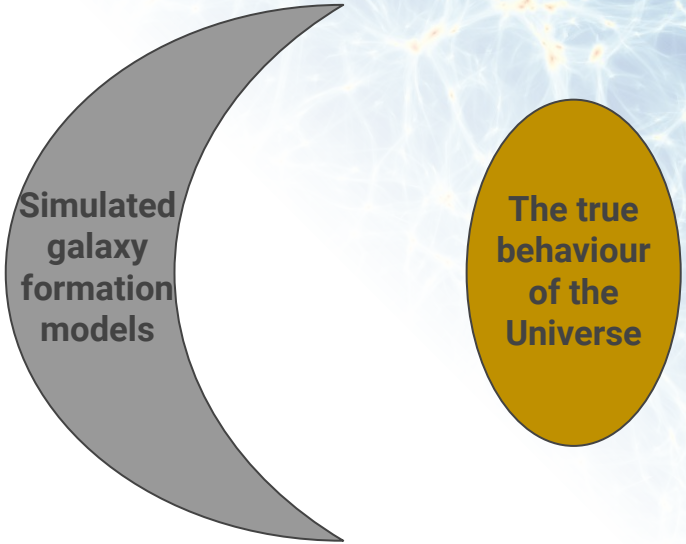
Marcos Pellejero Ibáñez, Raul Angulo, Matteo Zennaro, Jens Stücker, Francisco Maion, Rodrigo Voivodic, Giovanni Arico.

Cosmology from Home

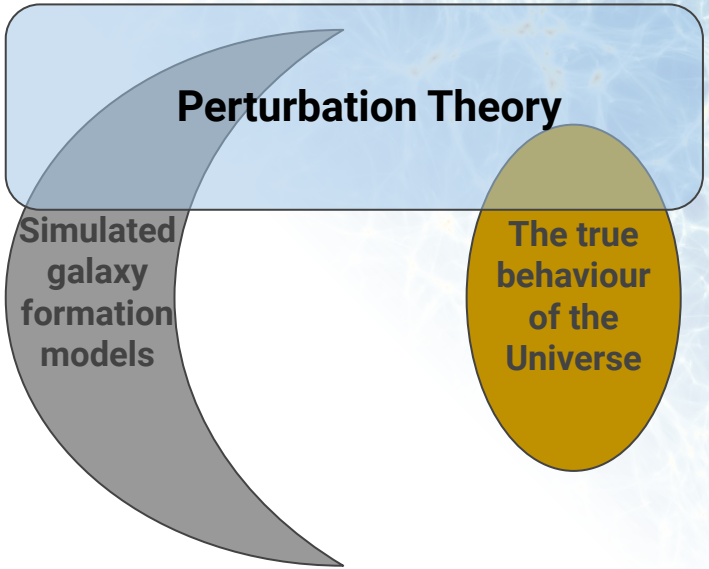
In a nutshell



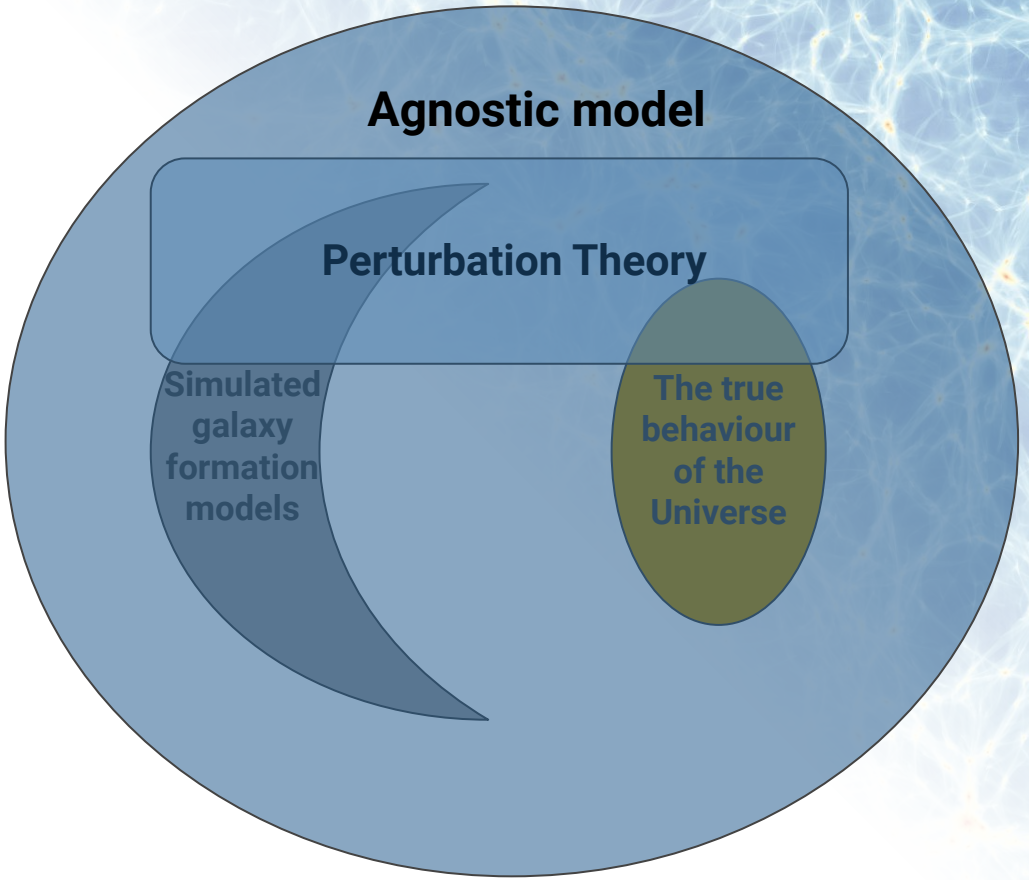
In a nutshell



In a nutshell

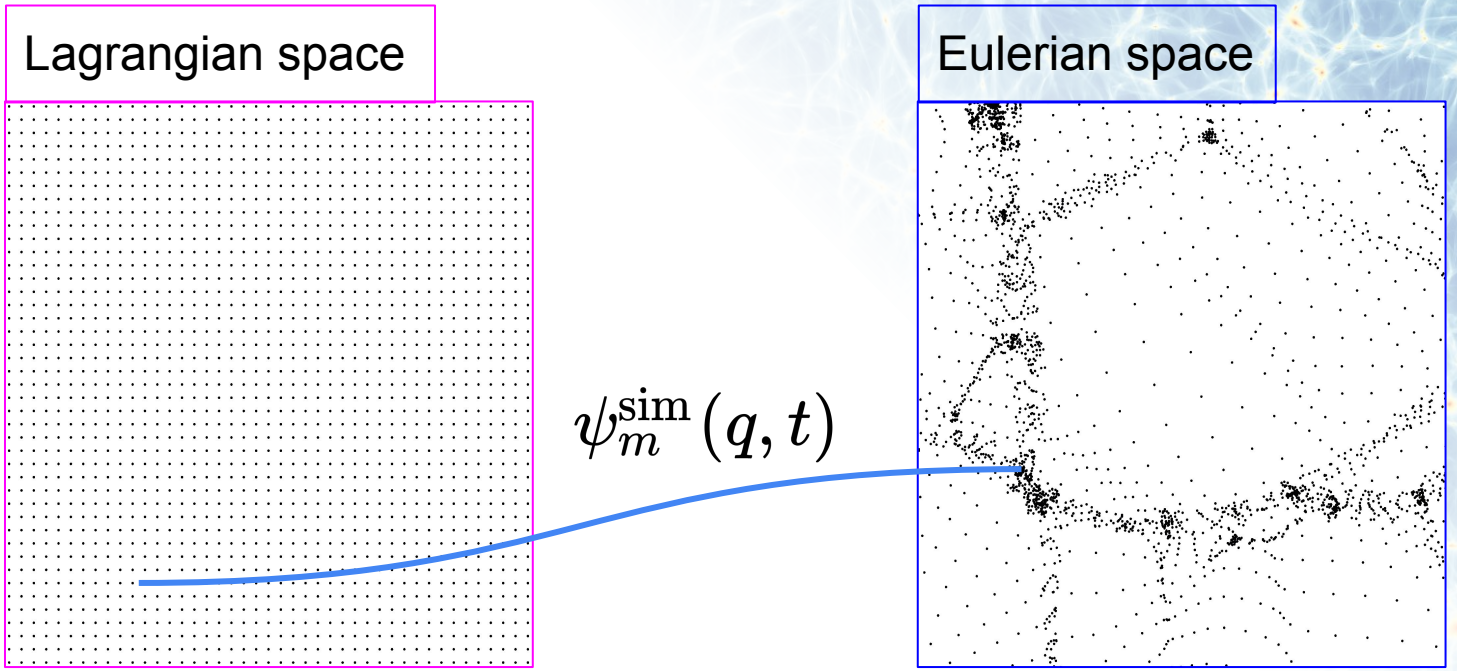


In a nutshell



1) **Advection:** Map lagrangian space into Eulerian space using N-body simulation displacement of DM particles.

$$1 + \delta(\boldsymbol{x}) = \int d^3q \delta_{\rm D}(\boldsymbol{x} - \boldsymbol{q} - \boldsymbol{\psi}(\boldsymbol{q}))$$



Credit image: Stuecker et al. (2020)

2) **Lagrangian space bias expansion:** Matter field to Galaxy field functional form

$$1 + \delta(\boldsymbol{x}) = \int d^3 q \delta_{\rm D}(\boldsymbol{x} - \boldsymbol{q} - \boldsymbol{\psi}(\boldsymbol{q}))$$

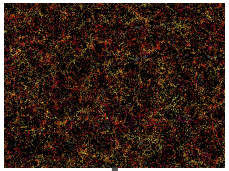
$$1 + \delta_{\rm g}(\boldsymbol{x}) = \int {\rm d}^3 q \, w(\boldsymbol{q}) \, \delta_{\rm D}(\boldsymbol{x} - \boldsymbol{q} - \boldsymbol{\psi}(\boldsymbol{q}))$$

Coming from N-body simulations

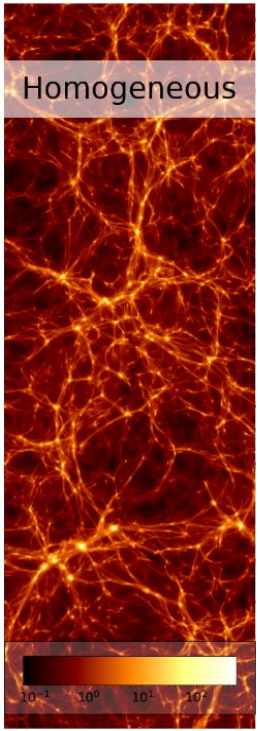
$$w(\boldsymbol{q}) = F(\delta_{\rm L}(\boldsymbol{q})) = 1 + b_1 \delta_{\rm L}(\boldsymbol{q}) + b_2 \left(\delta^2_{\rm L}(\boldsymbol{q}) - \langle \delta^2_{\rm L}(\boldsymbol{q}) \rangle\right) + b_s \left(s^2(\boldsymbol{q}) - \langle s^2(\boldsymbol{q}) \rangle\right) + b_\nabla \nabla^2 \delta_{\rm L}(\boldsymbol{q})$$

Modi et al. (2019)

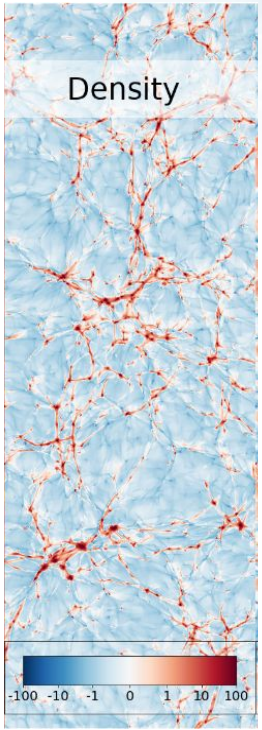
Advection + Bias Weights



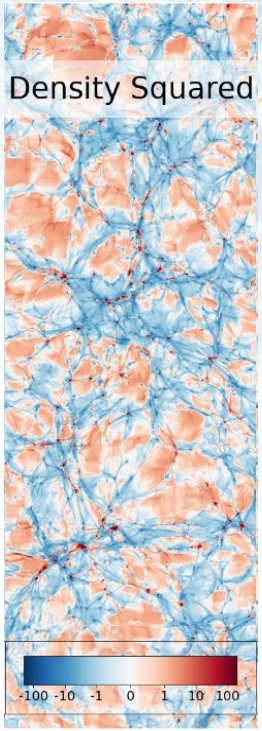
$$1 + \delta_{\rm g}(\boldsymbol{x}) =$$



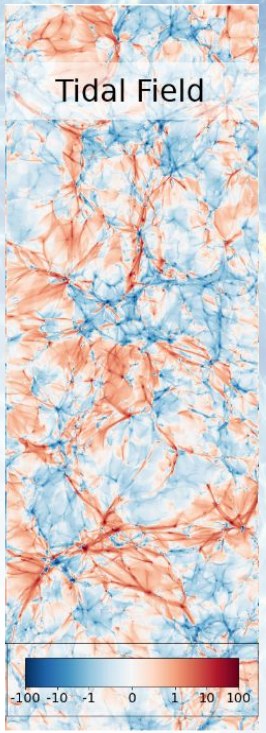
$+b_1$



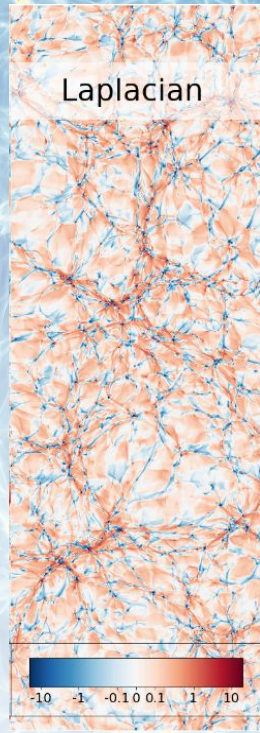
$+b_2$



$+b_{s^2}$



$+b_{\nabla^2}$



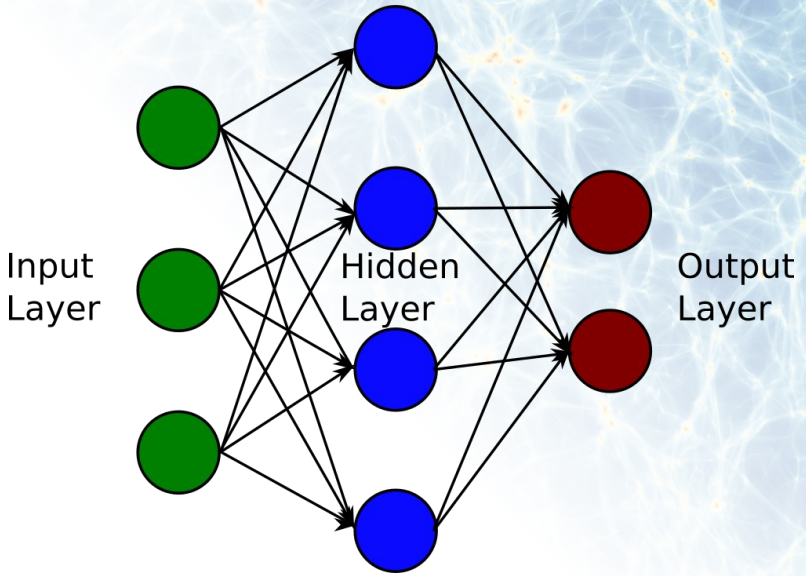
Credit image:
Zennaro et al.
(2020)

Make this model useful

Scale 4000 combinations of cosmological parameters and redshifts

Angulo & White (2009)

Compute model relevant statistics templates



trained Neural Network

(1 eval in ~ 40 ms)

Does it work?

Yes! At least at the level of 2-point statistics.

Down to scales of ~ 0.7 h/Mpc

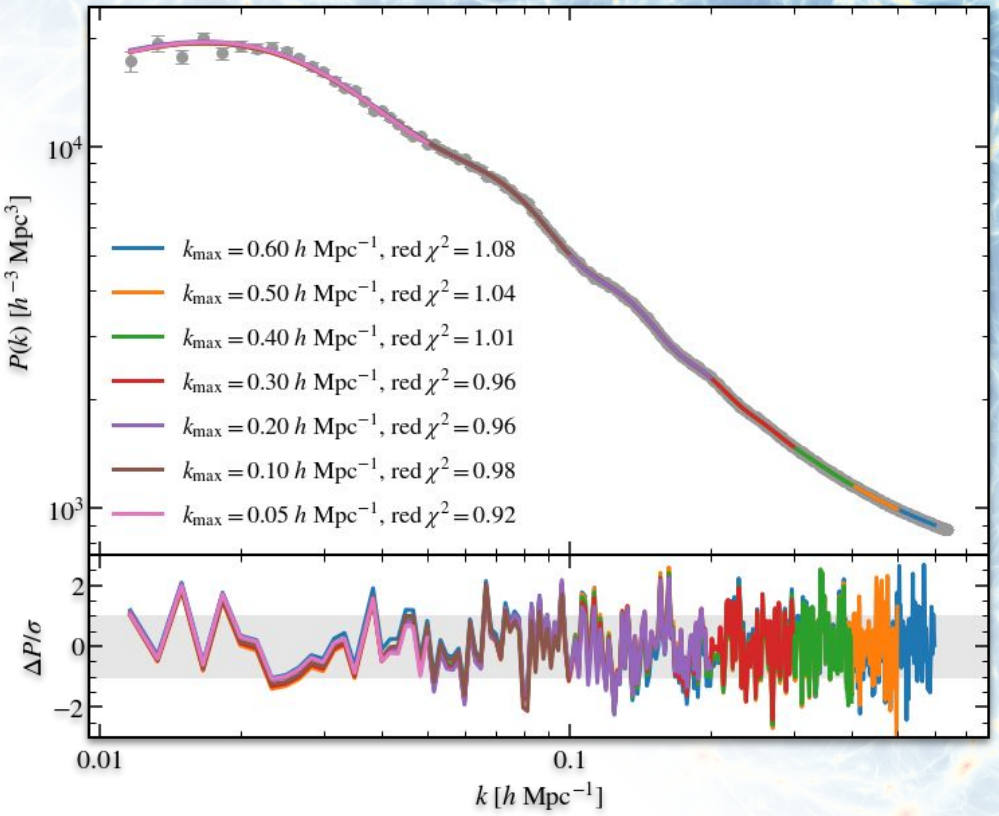


Figure Credit: Matteo Zennaro

Does it work?

With unbiased constraints!

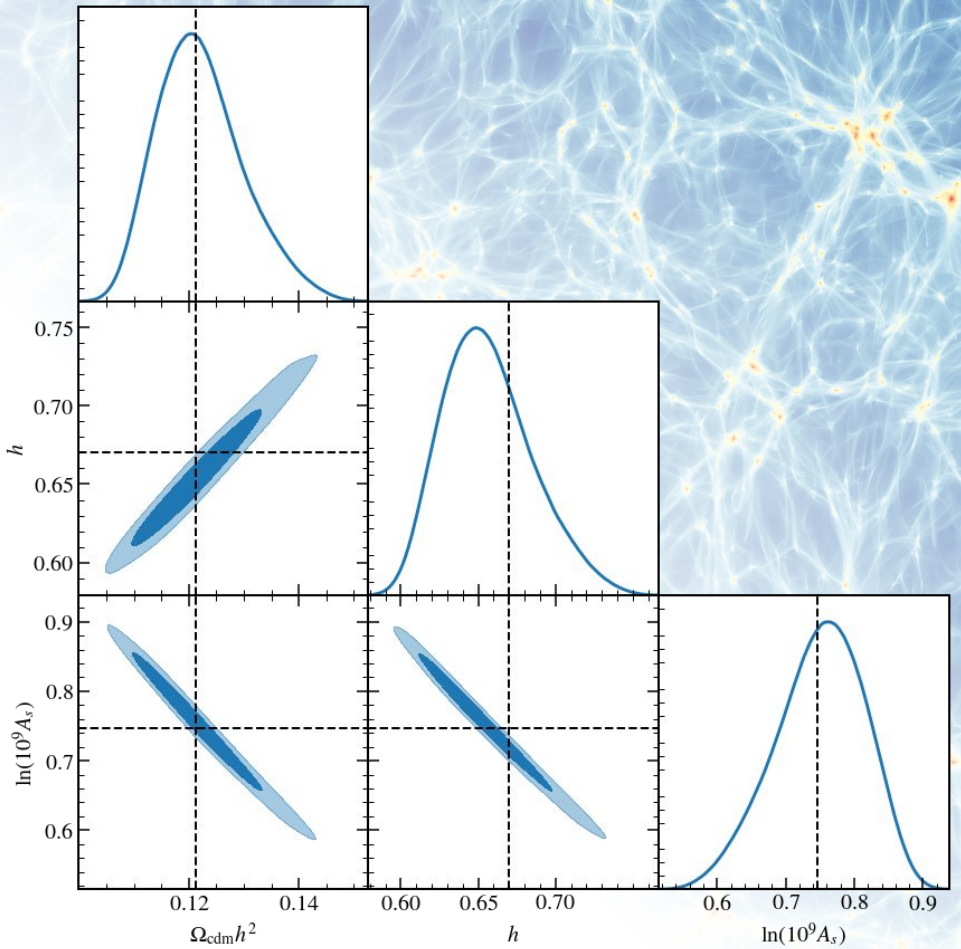
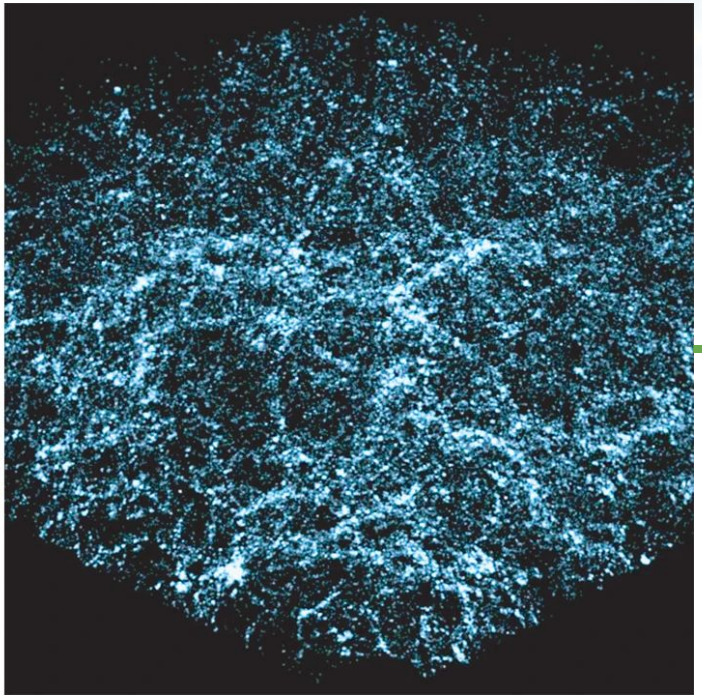


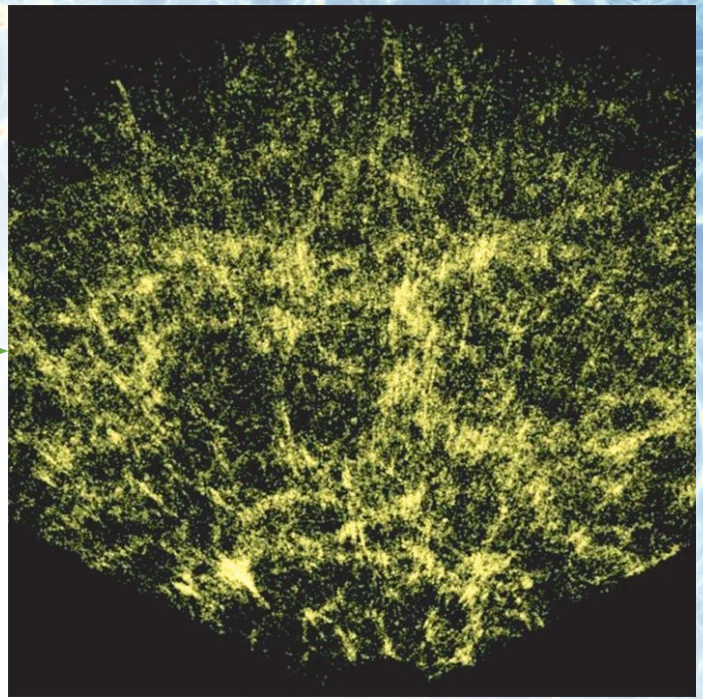
Figure Credit: Matteo Zennaro

Sadly, not everything is in real space

Real Space



Configuration Space (RSD)



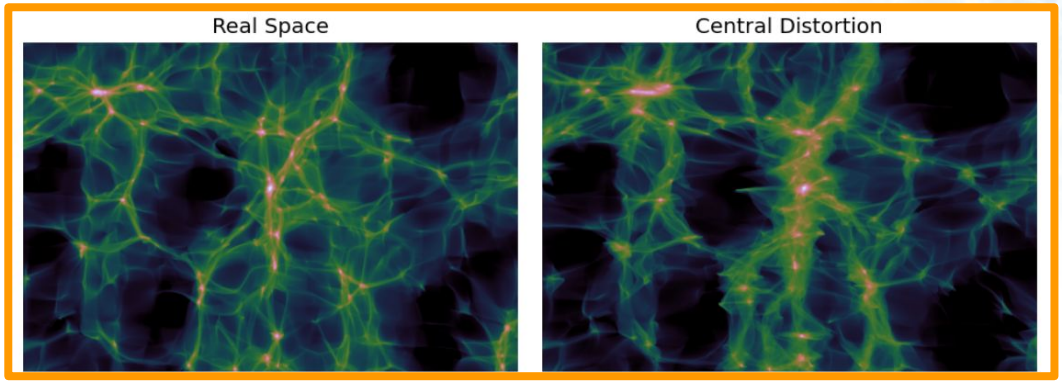
Credit image: Bianchini (2020)

Advection + Velocity assignment

$$1 + \delta_g^s(x) = \int d^3q\, w(q)\, \delta_{\rm D}\left(x - q - \psi^s(q)\right)$$

$$\psi^s(q_z) = \psi(q_z) + \frac{1}{aH(z)} v_{\rm tr}(q_z)$$

$$\boldsymbol{v}_{\rm tr} = \begin{cases} \boldsymbol{v}_{\rm DM}, & \text{if the tracer is outside of a halo} \\ \boldsymbol{v}_{\rm main\ sub}, & \text{if the tracer is inside of a halo} \end{cases}$$



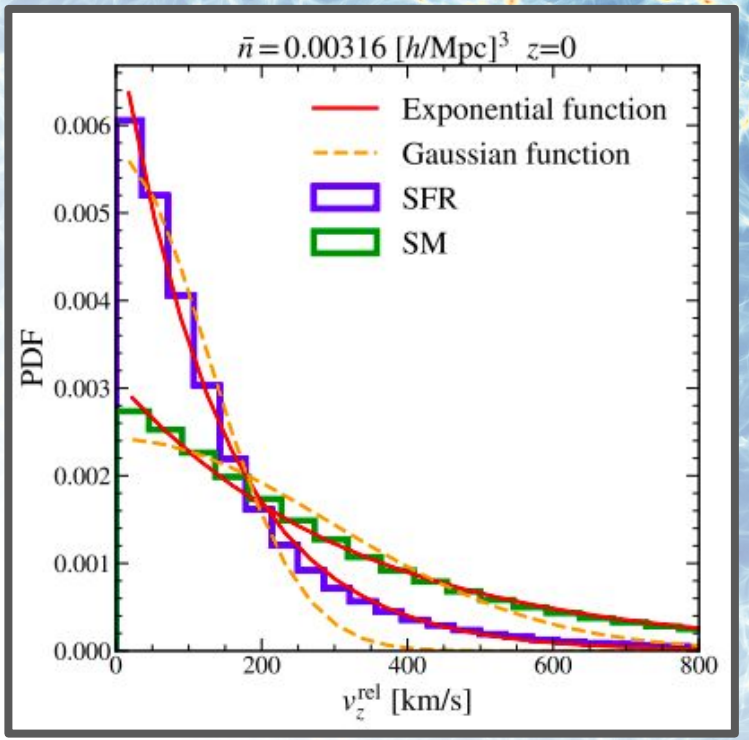
Pellejero-Ibañez et al. (2021)

Advection + Velocity assignment + velocity dispersion (FoG effect)

$$p(v_z) = (1 - f_{\rm sat})\delta_{\rm D}(v_z) + f_{\rm sat} \exp\left(-\lambda v_z\right)$$

$$\delta_{\rm tr}^{\rm FoG} = \delta_{\rm tr} *_z \left((1 - f_{\rm sat})\delta_{\rm D}(s_z) + f_{\rm sat} \exp\left(-\lambda_{\rm FoG} s_z\right)\right)$$

$$P_{\rm tr}^{\rm FoG}(k,\mu) = P_{\rm tr}(k,\mu)\left((1 - f_{\rm sat}) + f_{\rm sat}\frac{\lambda_{\rm FoG}^2}{\lambda_{\rm FoG}^2 + k^2\mu^2}\right)^2$$



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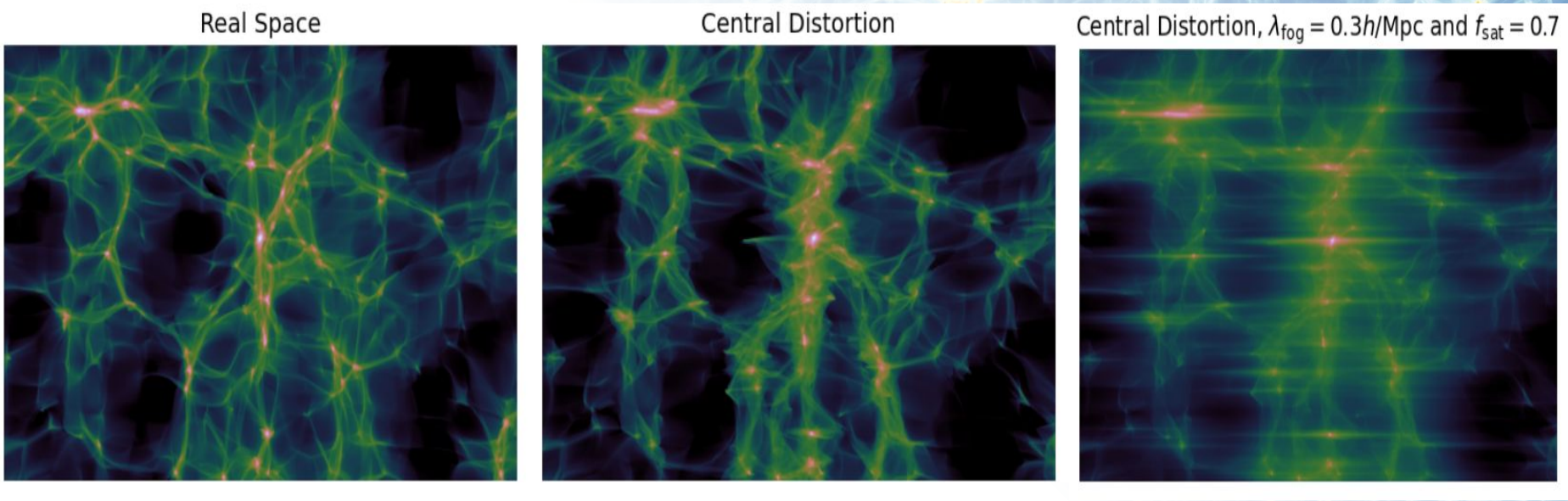

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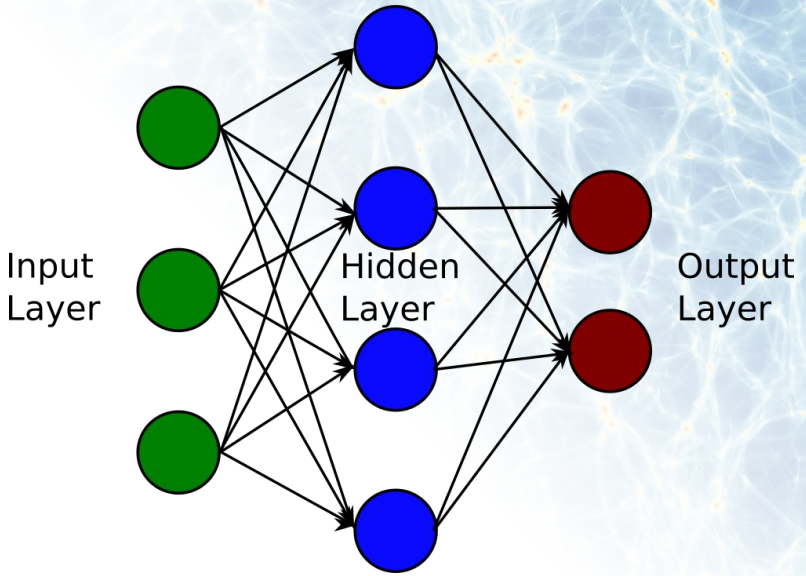

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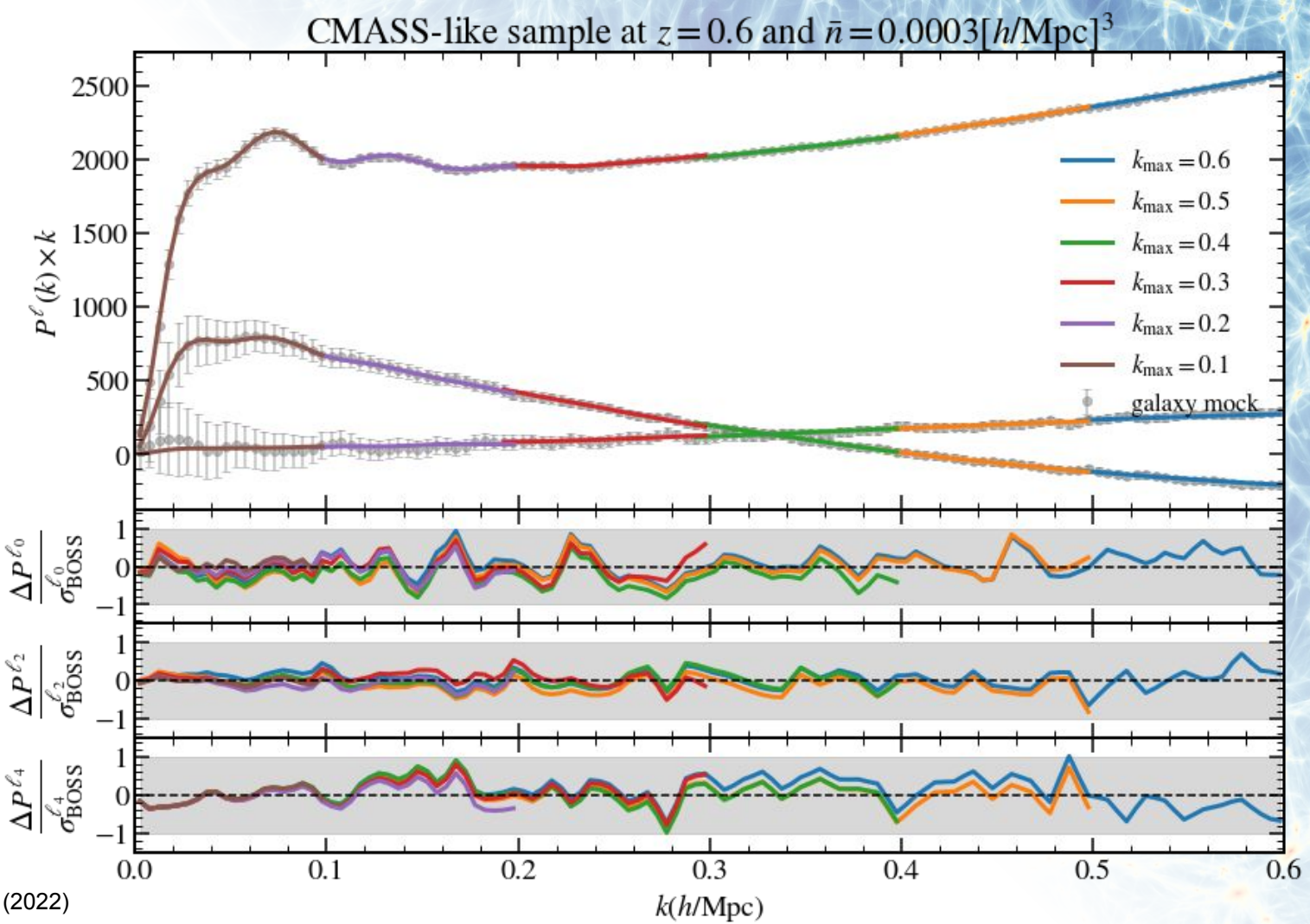
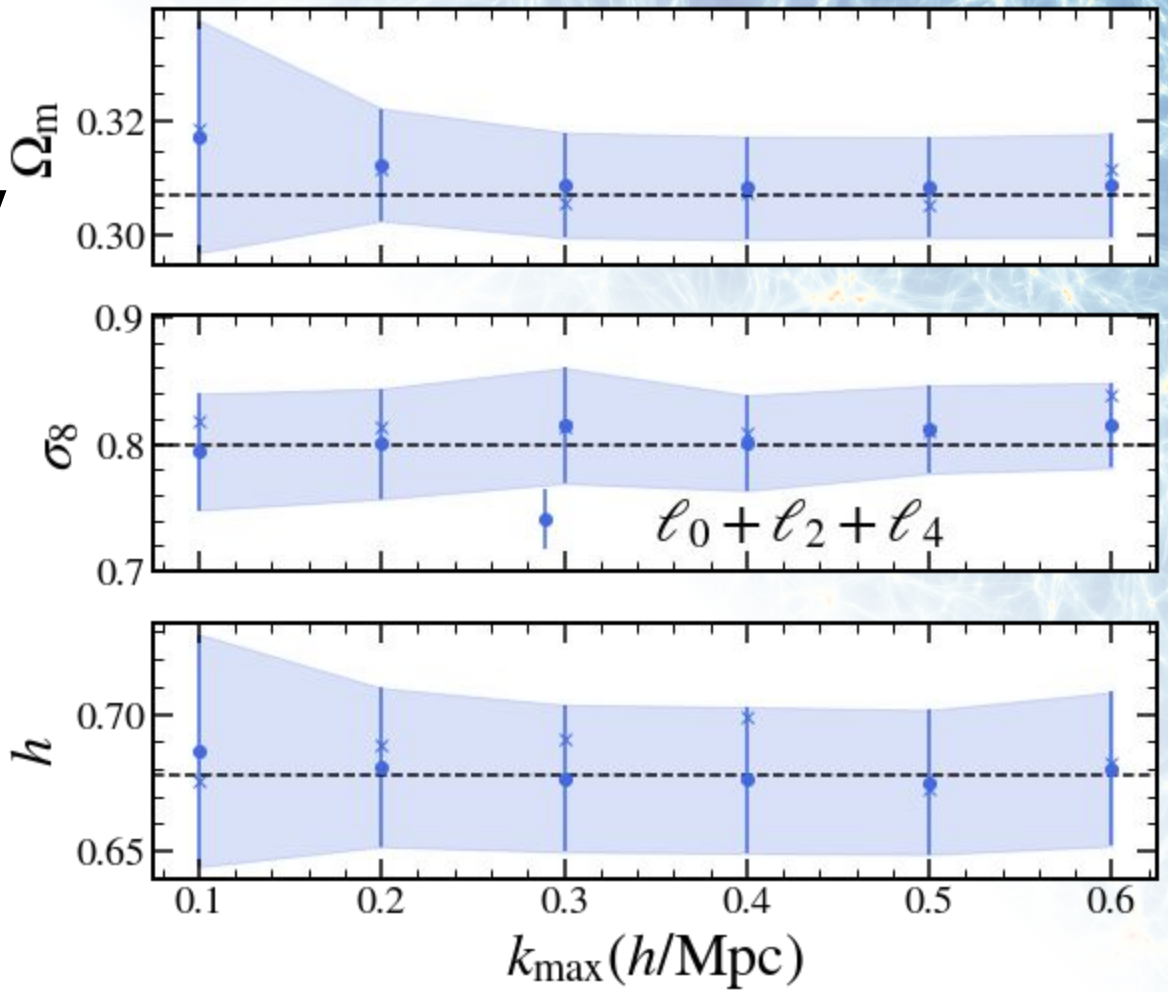
Does it work?: **Fit to CMASS mock**



Pellejero-Ibañez et al. (2022)

Does it work? : **Cosmology inference**



Pellejero-Ibañez et al. (2022)

Many thanks!