Mocking Cosmic Intensities: The tail of the HI luminosity function

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Outline

1. Mocking HI and the tail of the luminosity function.
2. The Peak Patch picture of Cosmic Catalogs
3. Multi-Scale Initial Conditions for Peak Patch
4. Measuring the bias with the Peak Background Split
5. Outlook

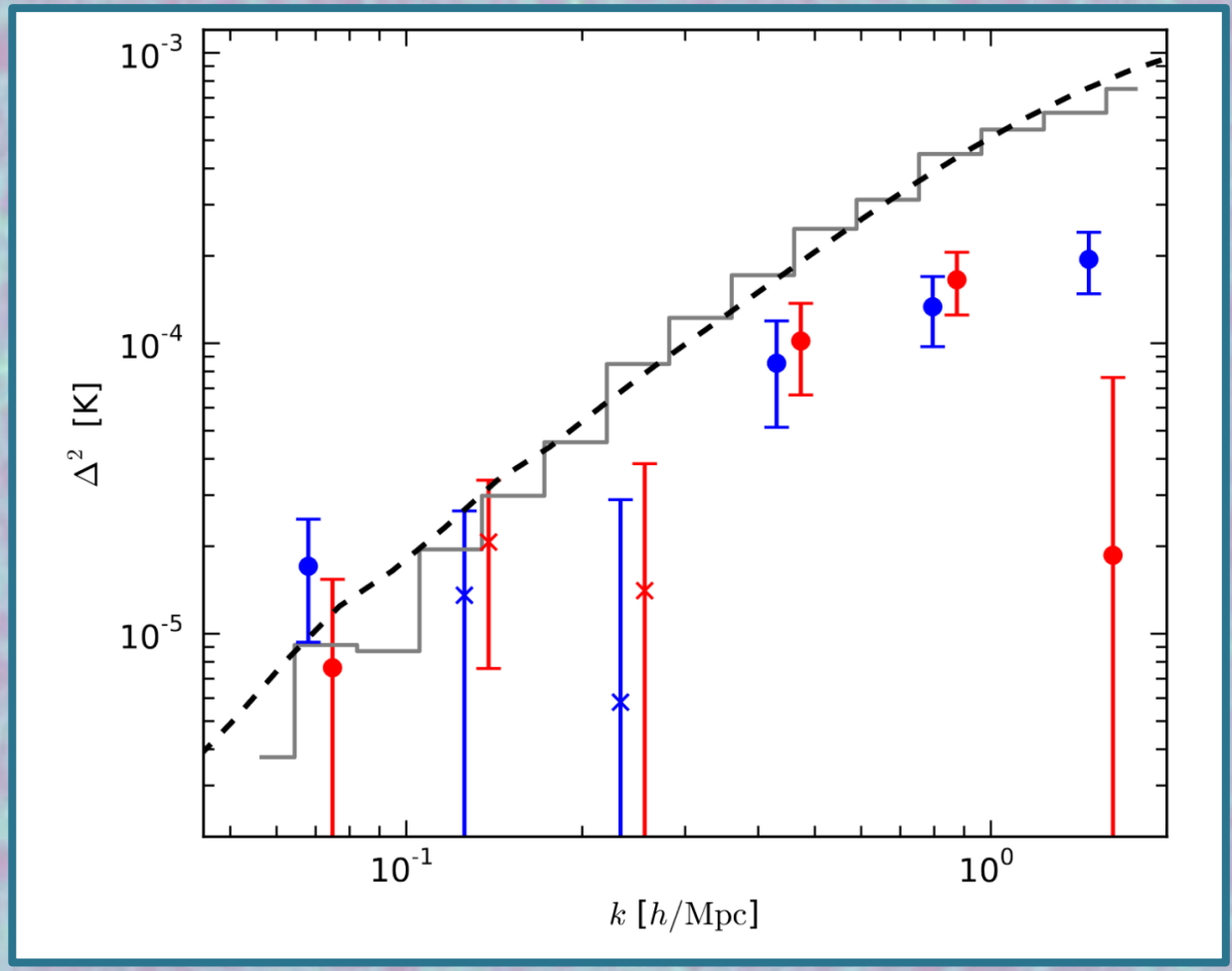
21 cm surveys with large fields of view

Also HERA, LOFAR, MWA, BINGO, ...

21 cm LIM will be a sensitive probe of HI in galaxies

- Anderson et al 2018
- Parkes x 2dF
- Mean z~0.1

- Good dataset to test new methods on.



IM surveys with large fields of view

…. need mocks.

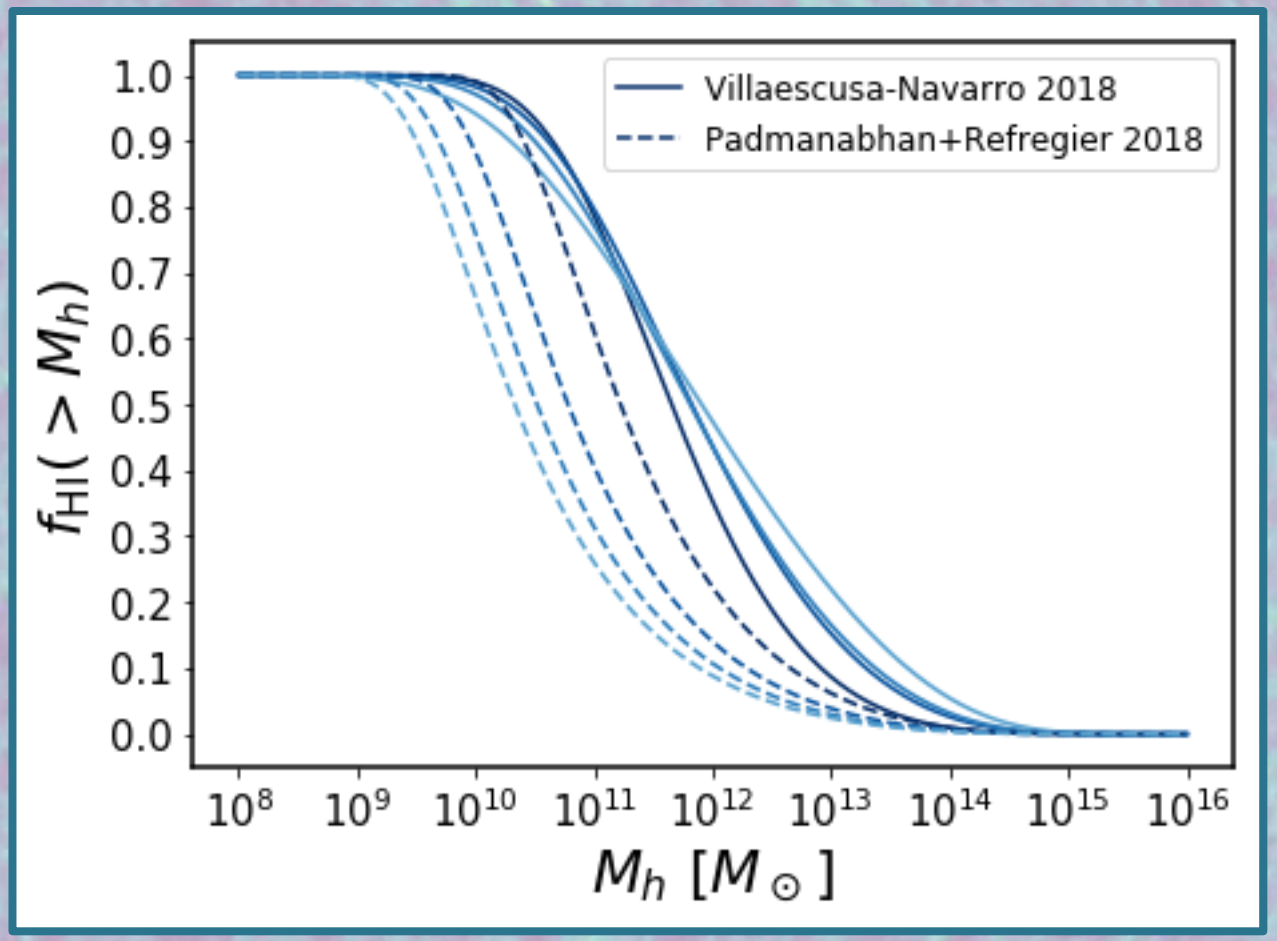
IM surveys with large fields of view

…. need (fast and accurate) mocks.

Would like to construct a halo model for HI…

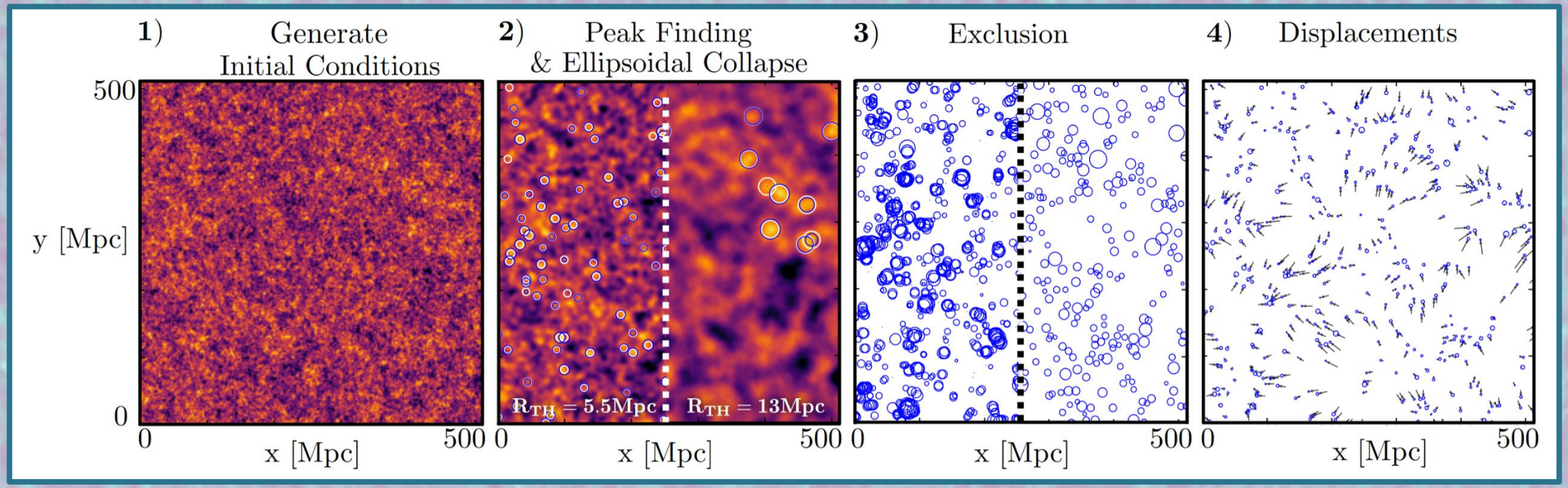
Increasing redshift (0, 1, 2, 3) with decreasing opacity.

$$f_{HI}(> M_h) = \frac{1}{\Omega_{HI}} \int_{M_h}^{\infty} dM \; M_{HI}(M) \frac{dn(M)}{dM}$$



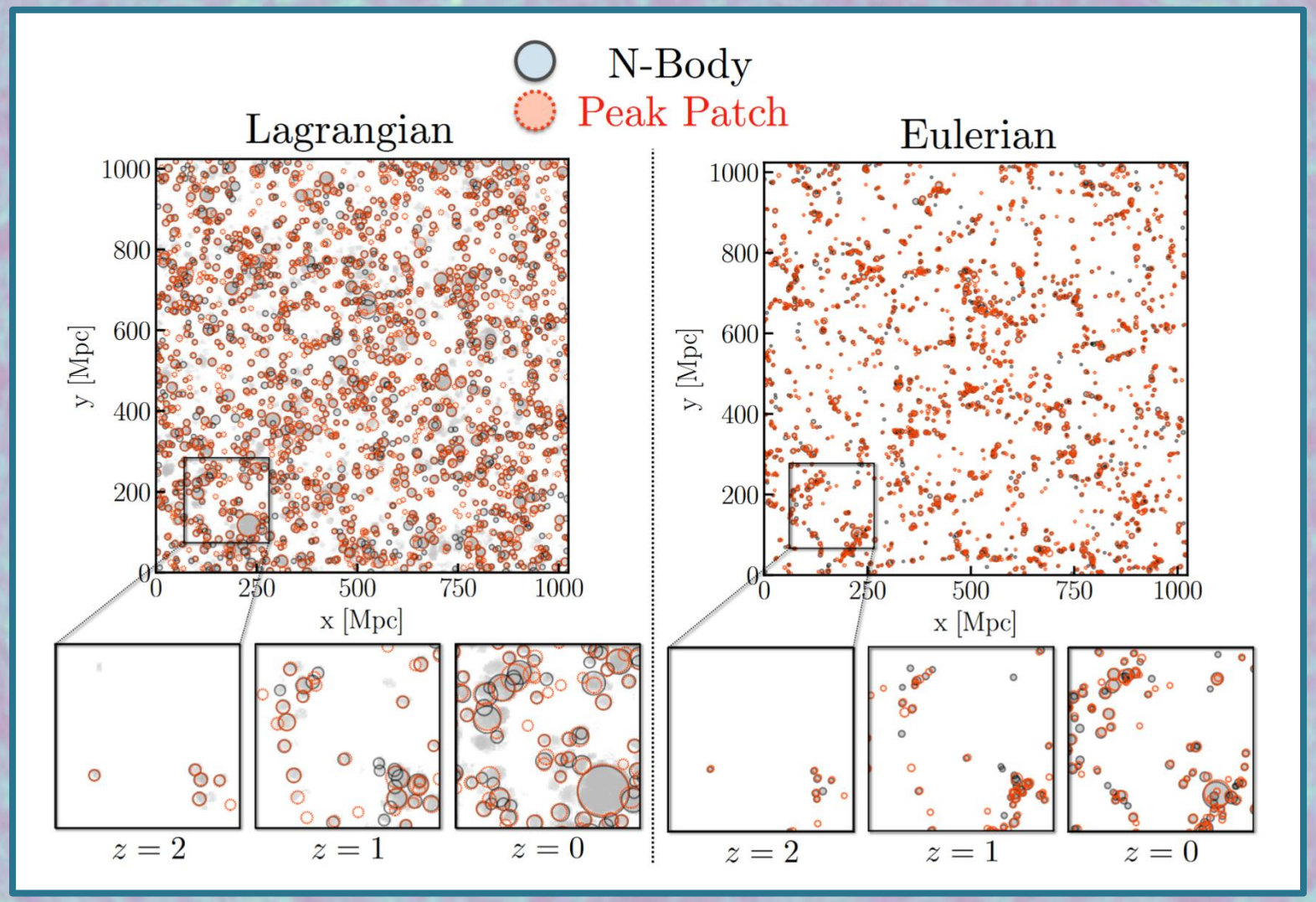
The Peak Patch method (for mocking dark matter halo catalogs)

$$\frac{\ddot{x}_i}{x_i} = \frac{\ddot{a}}{a} - \frac{1}{2}\Omega_m H^2 \left[b_i \bar{\delta} + c_i \bar{\delta}_{\rm lin} \right]$$



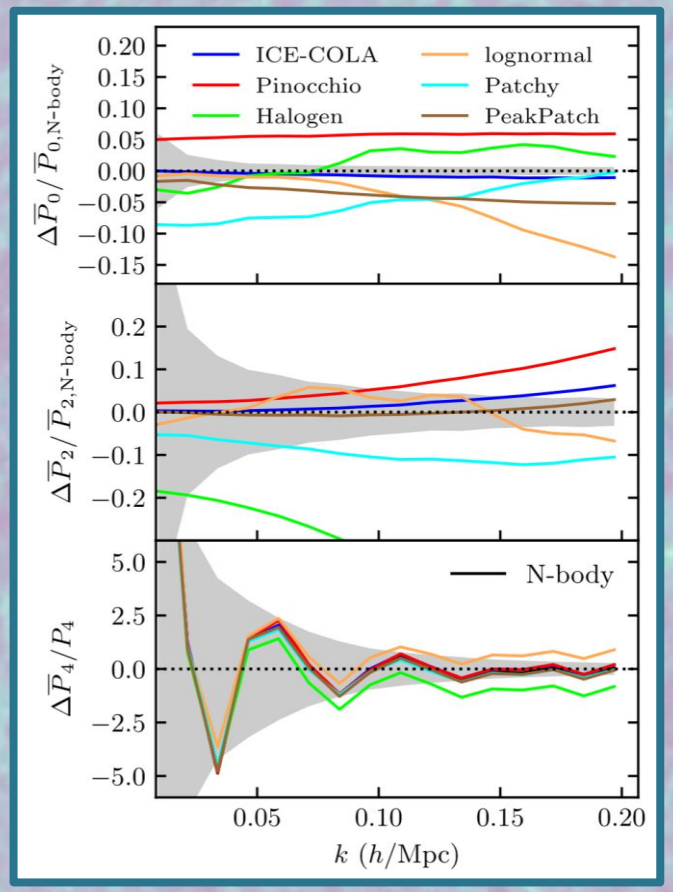
Bond & Myers 1996, G. Stein et al. 2018

The Peak Patch method

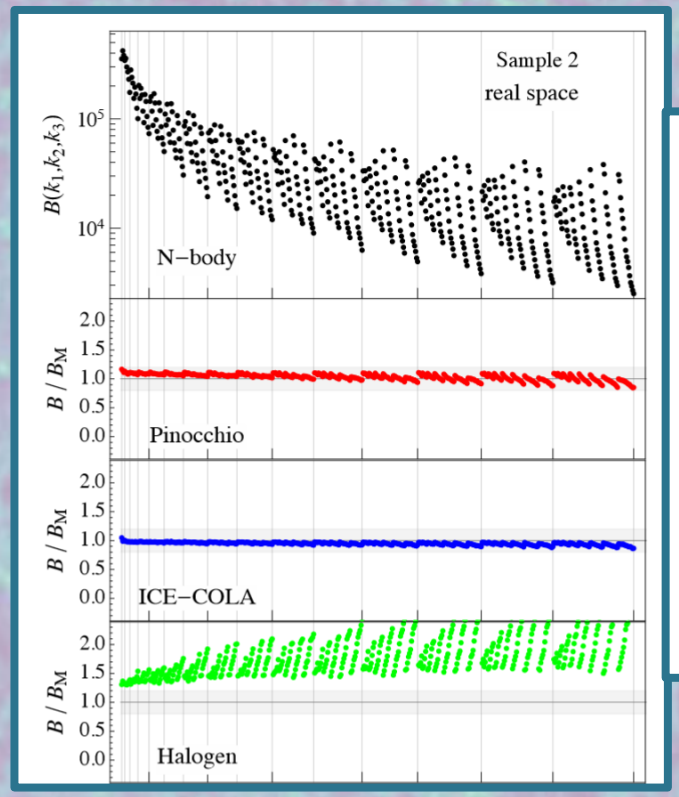


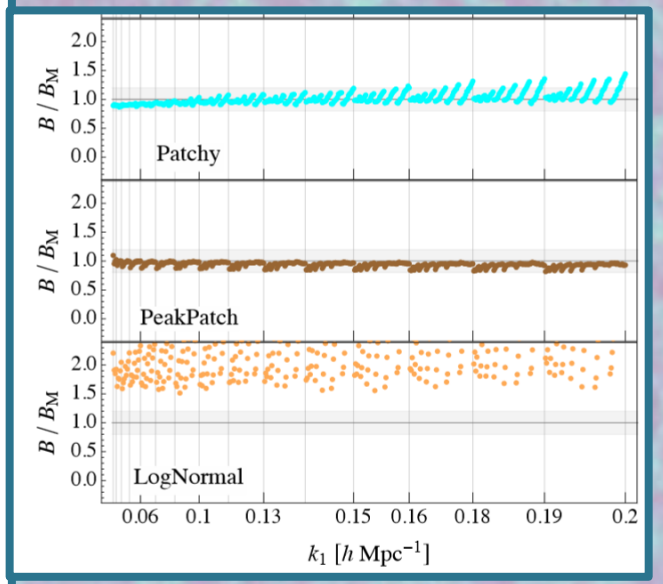
The Peak Patch method

Power spectrum multipoles



Bispectrum





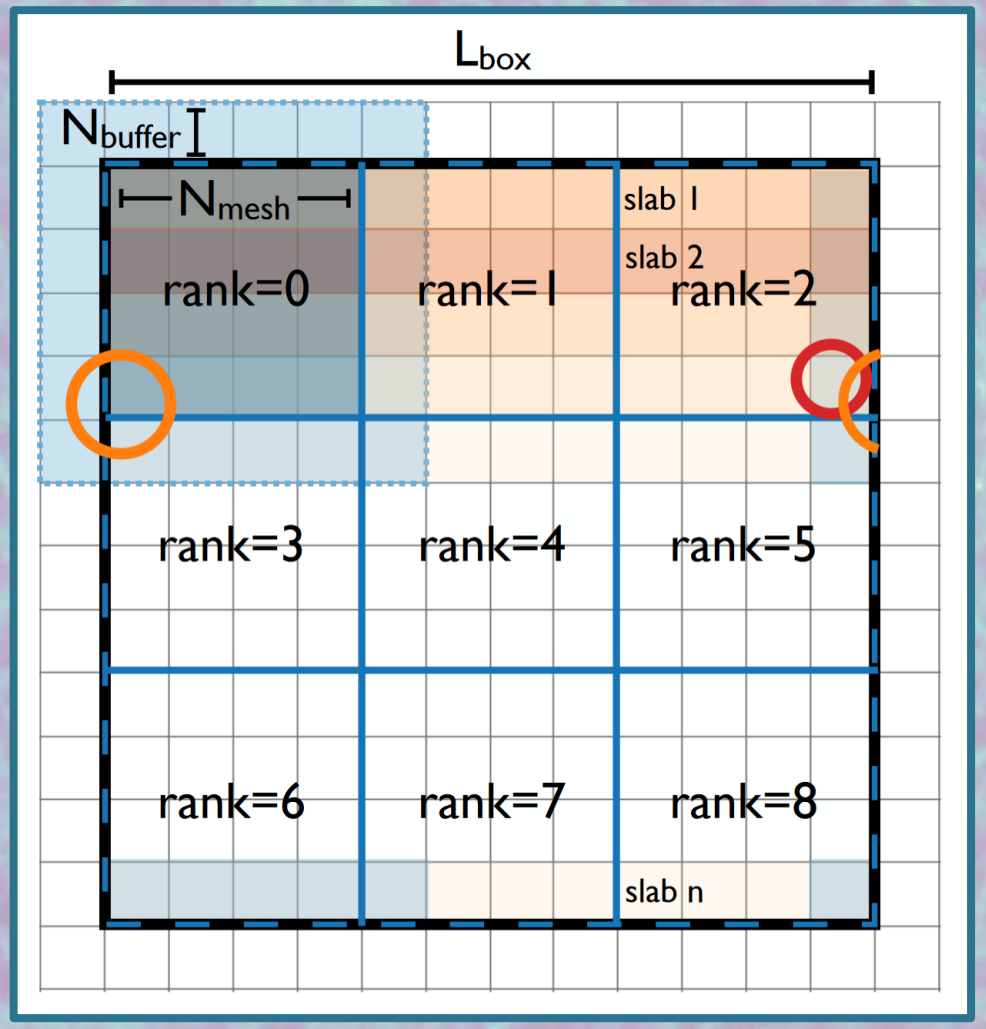
Lippich et al. 2018; Blot et al. 2018; Colavincenzo et al. 2018

The Peak Patch method

- Performs well in comparison to N-body, and quite well compared to other methods.
- Is computationally cheap.
- Is mostly local...

The Peak Patch method

The most non-local step is the generation of initial conditions, which need to be coherent across the entire simulation volume.

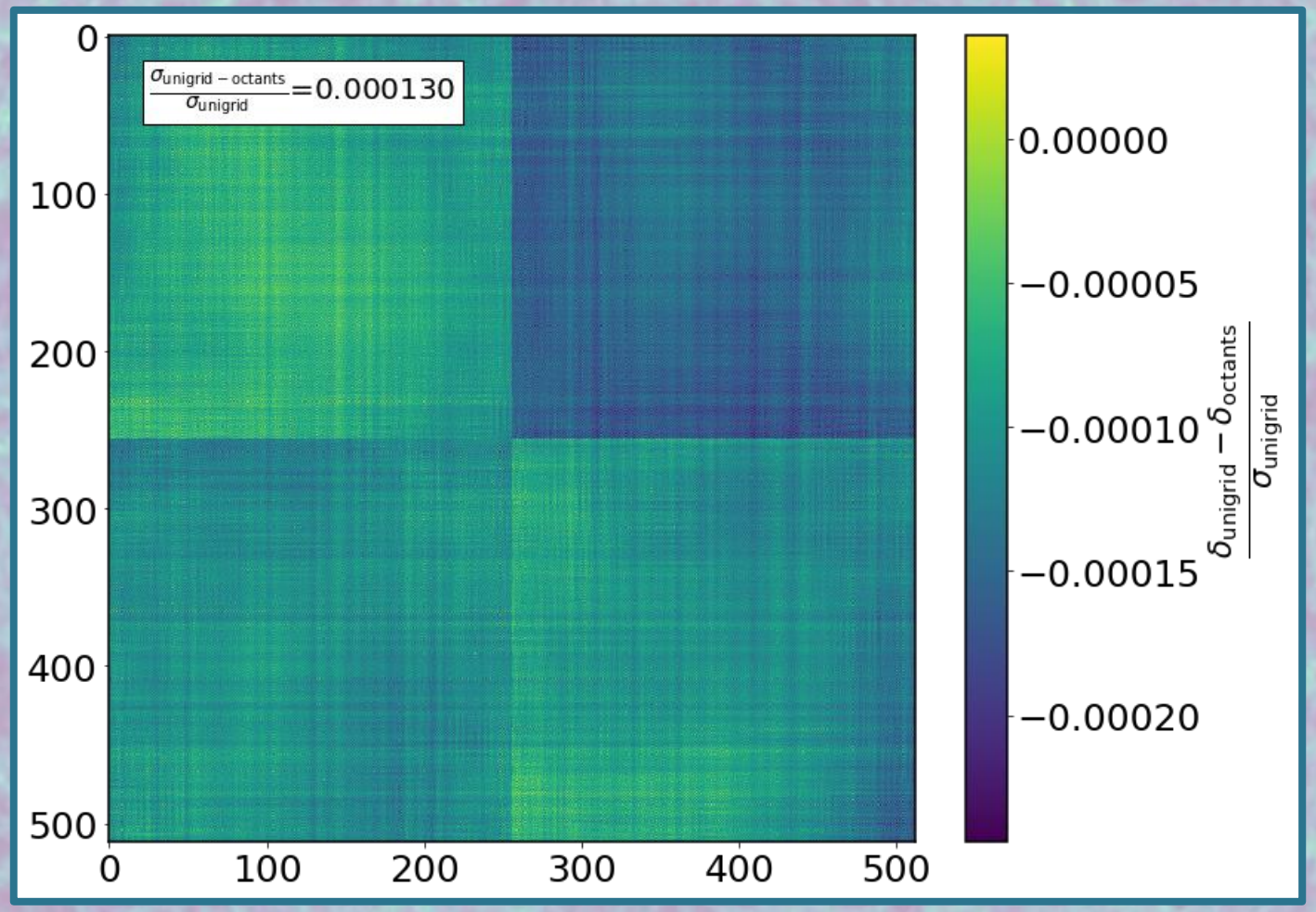


Multi-Scale Initial Conditions (MUSIC – Hahn & Abel 2011)

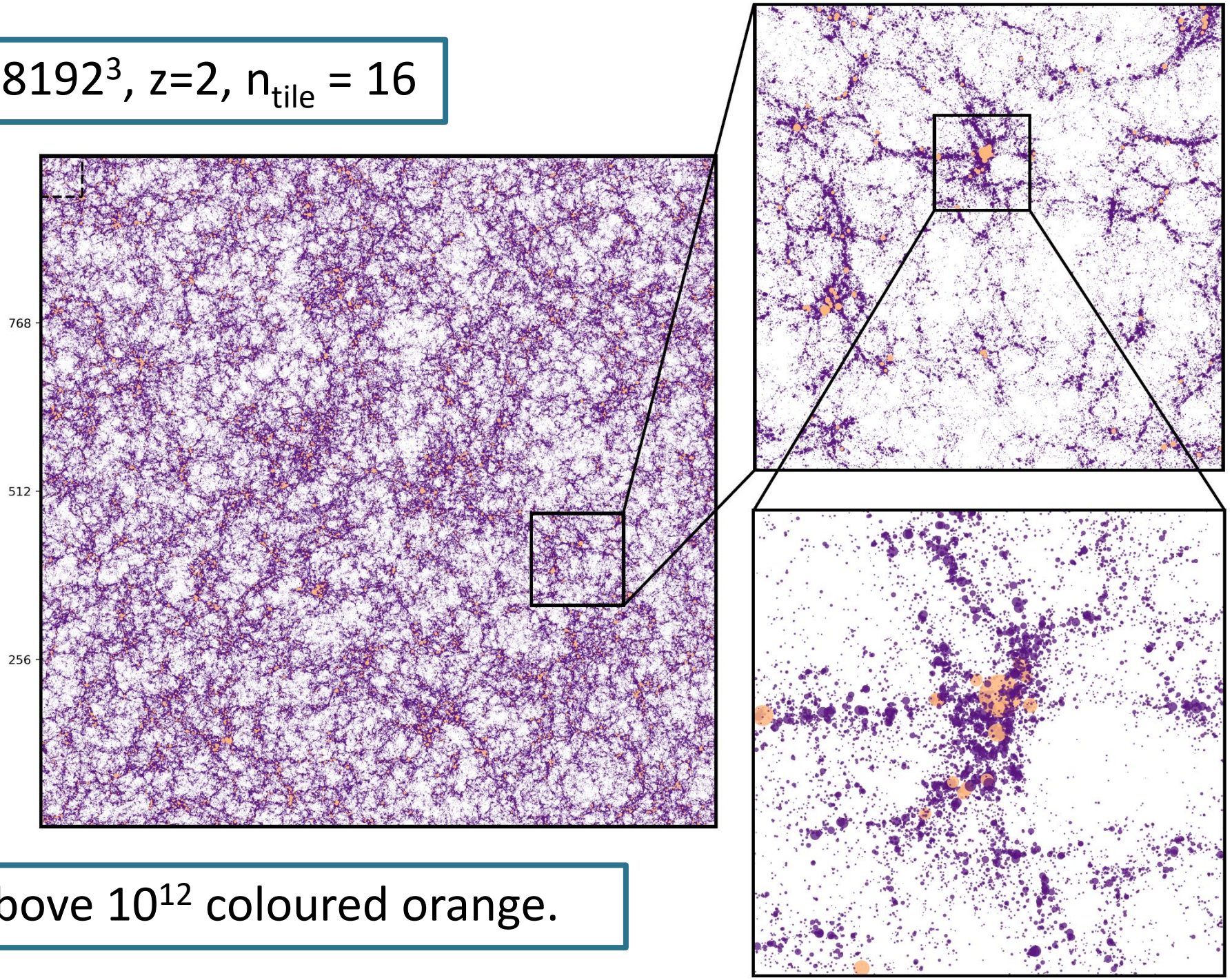
ABSTRACT

We discuss a new algorithm to generate multi-scale initial conditions with multiple levels of refinements for cosmological "zoom-in" simulations. The method uses an adaptive convolution of Gaussian white noise with a real space transfer function kernel together with an adaptive multi-grid Poisson solver to generate displacements and velocities following first (1LPT) or second order Lagrangian perturbation theory (2LPT). The new algorithm achieves RMS relative errors of order 10^{-4} for displacements and velocities in the refinement region and thus improves in terms of errors by about two orders of magnitude over previous approaches. In addition, errors are localized at coarse-fine boundaries and do not

Multi-Scale Initial Conditions for Peak Patch

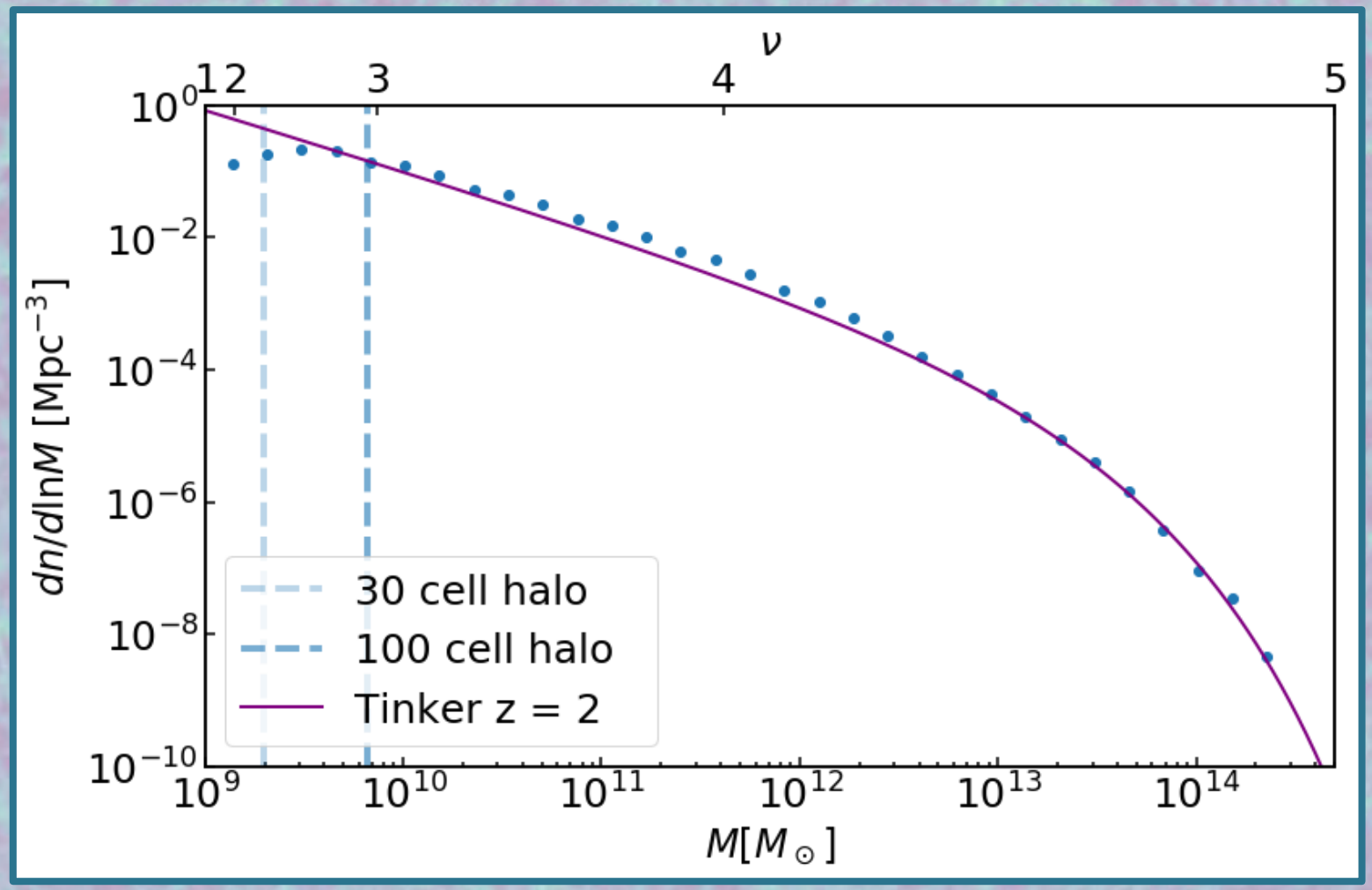


1 Gpc^3, 8192^3, z=2, n_{tile} = 16

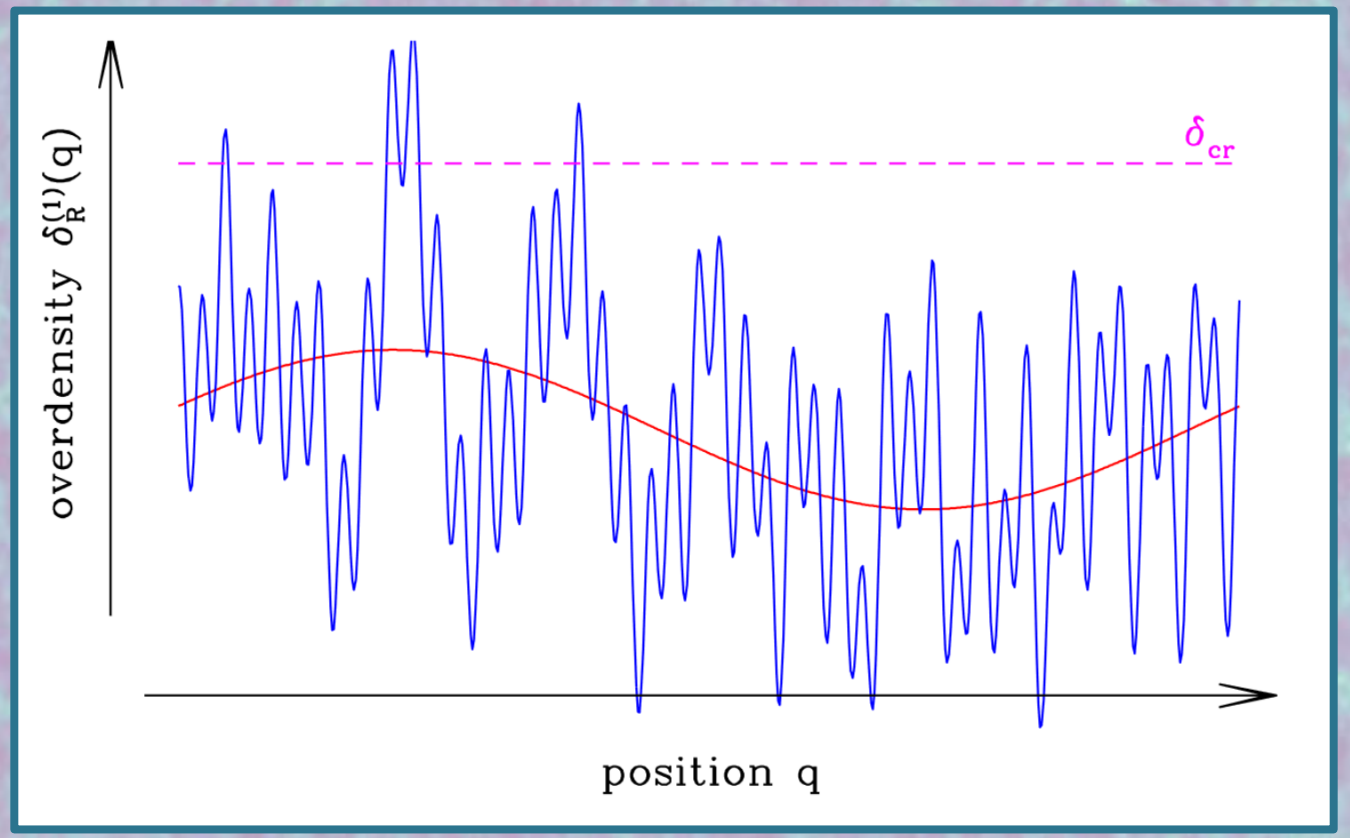


Halos above 10^{12} coloured orange.

High-resolution cosmo sim



The Peak Background Split



The Peak Background Split

$$\begin{aligned}\delta_g(\mathbf{x}, M, \delta_{\rm sc}) &\equiv \frac{n_g(\mathbf{x}, M, \delta_{\rm sc})}{\bar{n}_g(M, \delta_{\rm sc})} - 1 \\ &\approx \frac{\bar{n}_g(M, \delta_{\rm sc} - \delta_l(\mathbf{x}))}{\bar{n}_g(M, \delta_{\rm sc})} - 1 \\ &\approx -\frac{1}{\bar{n}_g}\frac{d\bar{n}_g}{d\delta_{\rm sc}}\delta_l(\mathbf{x}) + \frac{1}{2}\left(\frac{1}{\bar{n}_g}\frac{d^2\bar{n}_g}{d\delta_{\rm sc}^2}\right)\left[\delta_l(\mathbf{x})\right]^2 + \ldots\end{aligned}$$

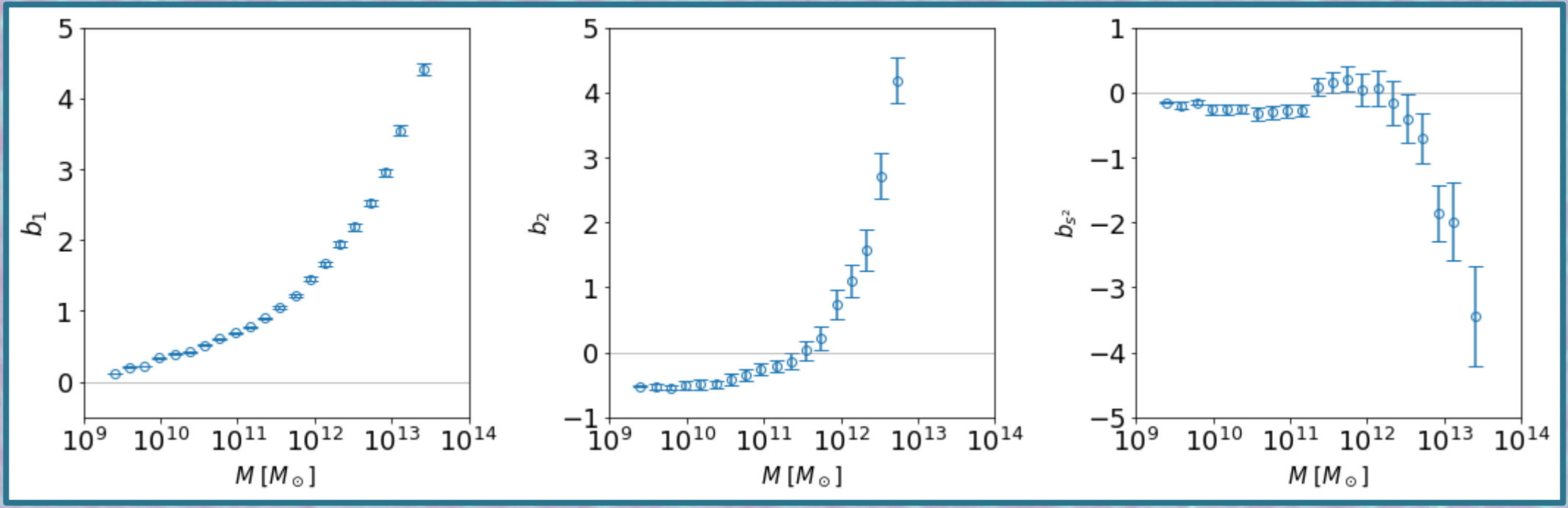
… can be shown to be exact, using “separate universe” arguments.
This gives a simple interpretation of the bias parameters, and a nice method for calculating them.

See e.g. Schmidt et al 2013, Desjacques et al 2016, Modi et al 2018

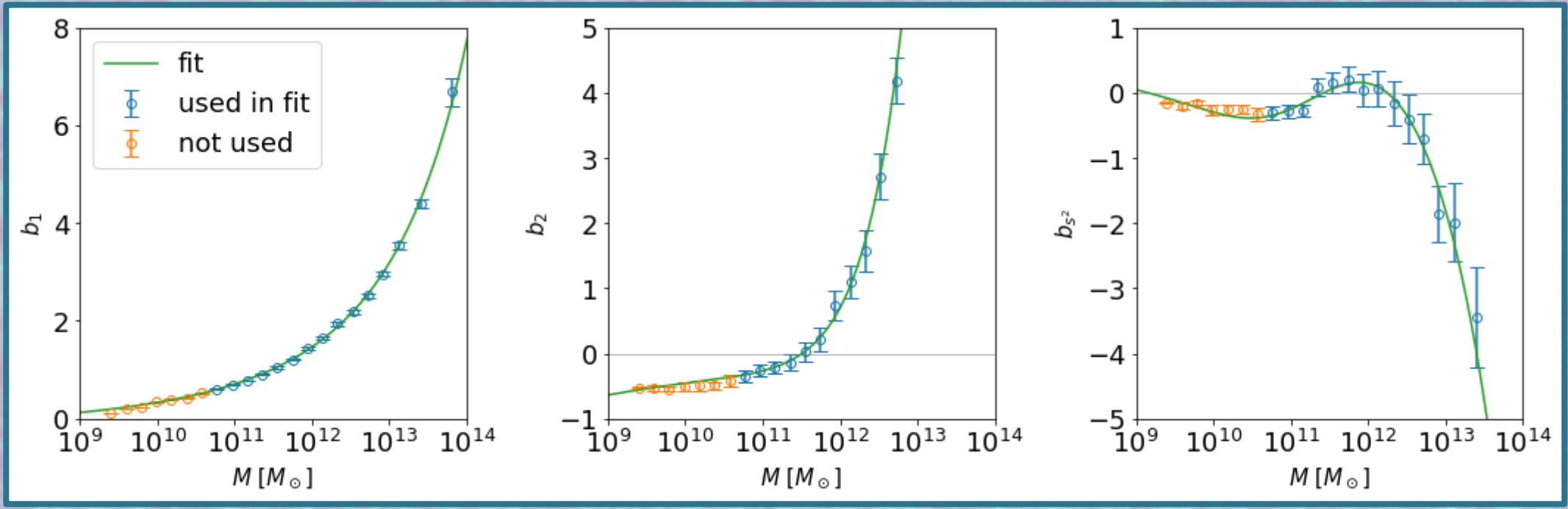
Lagrangian bias

$$\delta_g(x) = b_1\delta_L(x) + b_2\delta_L^2(x) + b_{s^2}s^2(x)$$

$$s^2(x) = \sum s_{ij}^2, \qquad s_{ij} = \frac{\partial_i\partial_j}{\nabla^2}\delta_L(x)$$



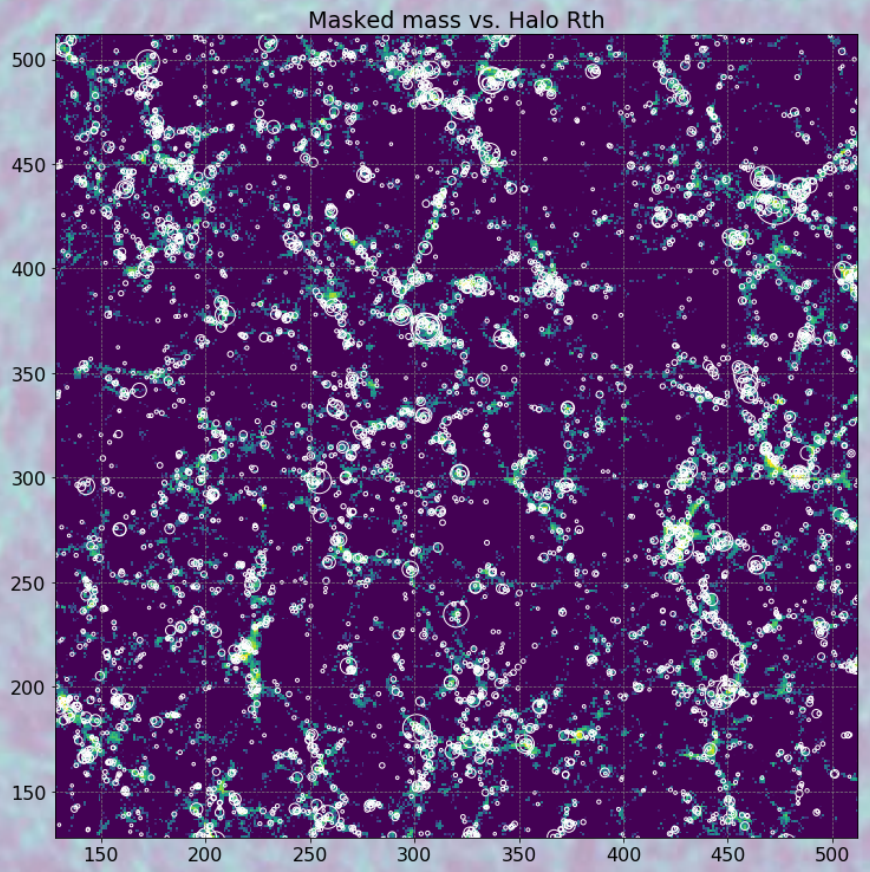
Lagrangian bias



cal-sky - github.com/marcelo-alvarez/cal-sky

- Fully parallel 2LPT code (written in C++).
- Allows you to supply a halo catalog which it cuts out from the field.
- Has options for painting on various LSS tracers.
- Currently implementing Lagrangian biasing of the field component…

Subgrid


Masked mass vs. Halo Rth
500
450
400
350
300
250
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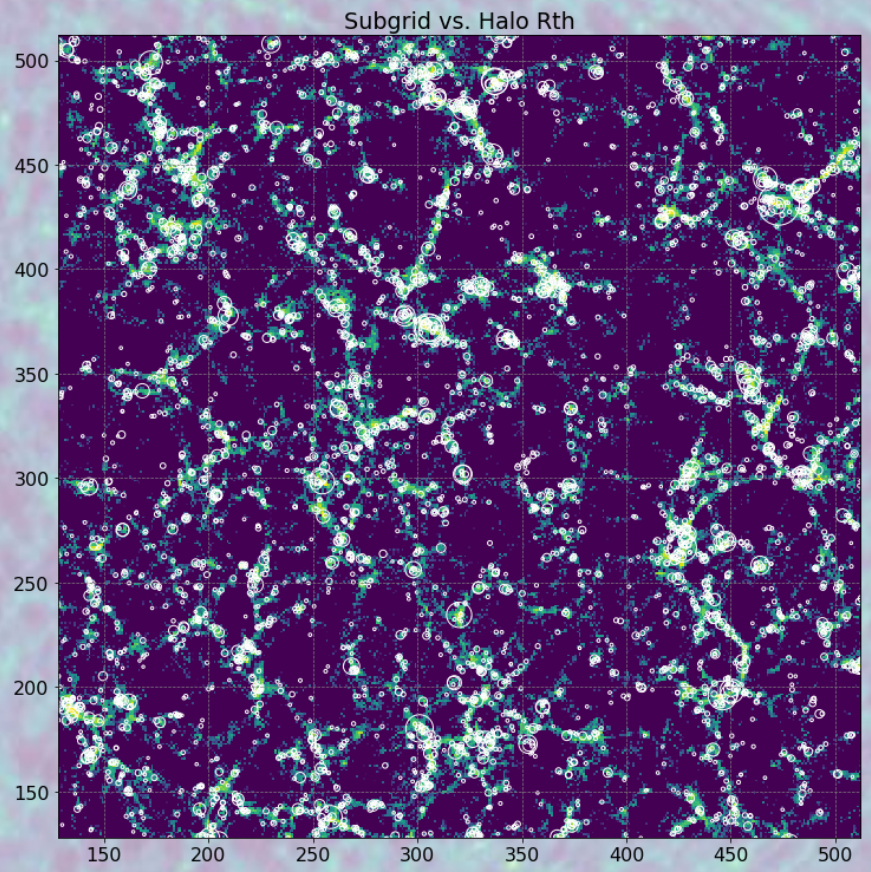
400
450
500


Subgrid vs. Halo Rth
500
450
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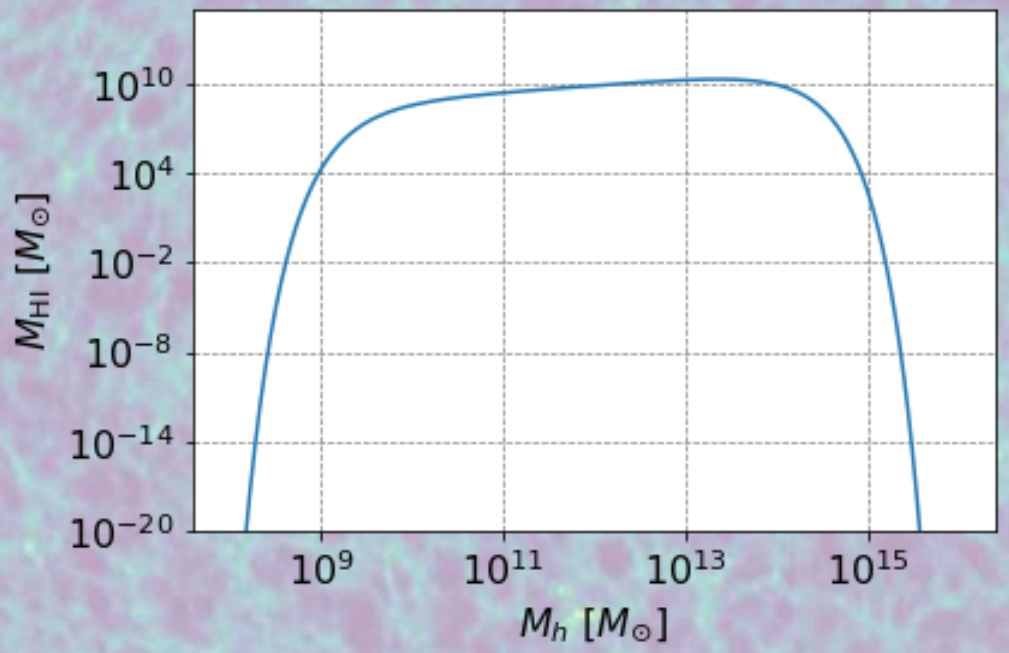
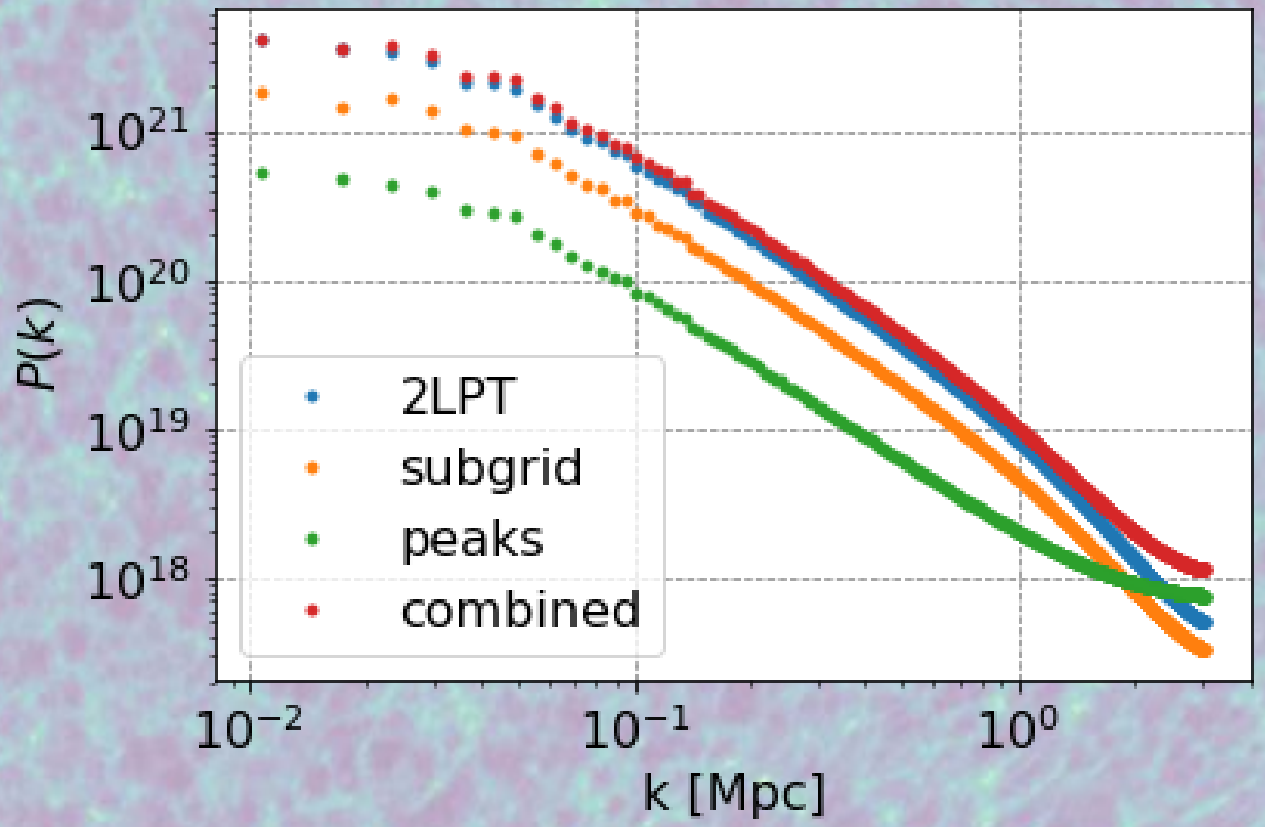
HI model for subgrid, Padmanabhan + Refregier 2016





Questions?