eBOSS Quasar Mock Challenge

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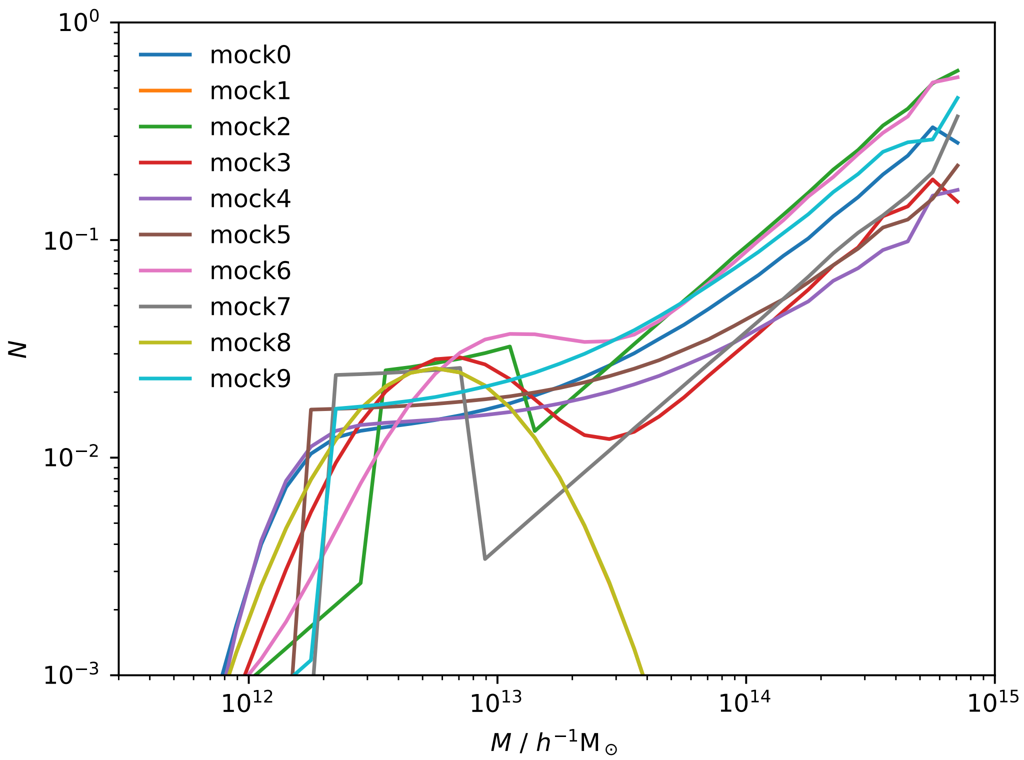
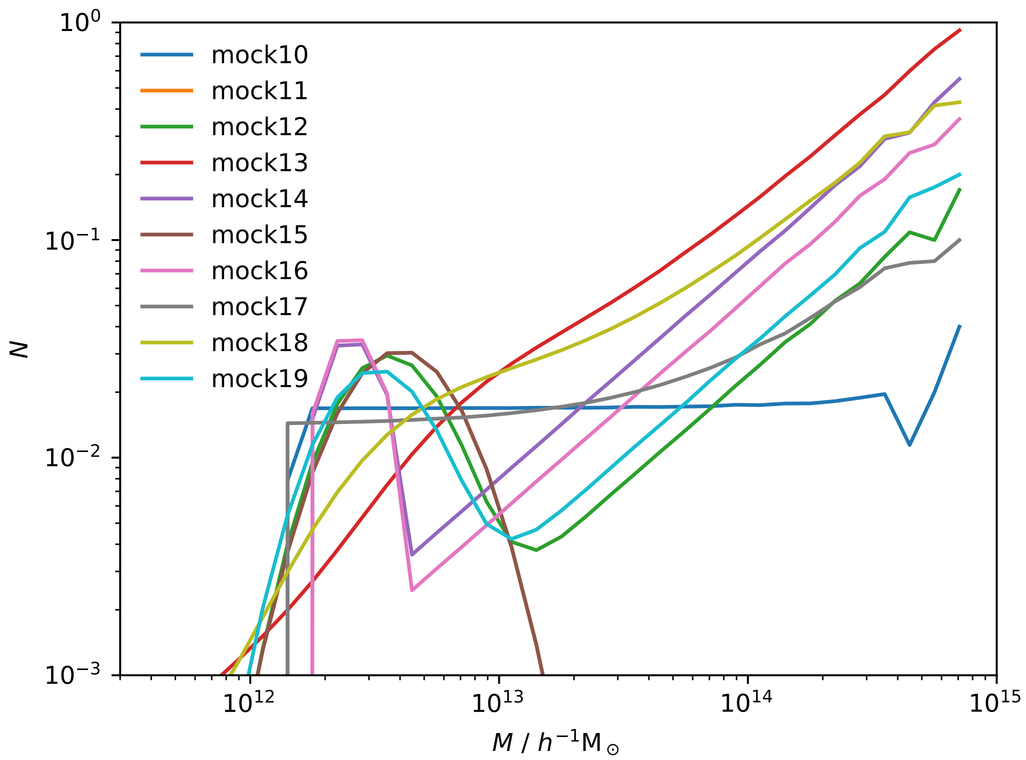
Outline

- Aim is to validate models used in RSD analysis
- Understand errors on $f\sigma_8$, $\alpha_\parallel$, $\alpha_\perp$
- Use HOD mocks created from OuterRim simulation
- Non-blind challenge, where cosmology is known
- Blind challenge, where simulation cosmology has been modified
- Method of Mead & Peacock to scale simulation cosmology

Non-blind mocks

- 20 HODs, 100 mocks for each
- OuterRim simulation snapshot at z=1.433
- In cubic box (3 Gpc/h), in WMAP7 cosmology
- Mocks have approximately the same large-scale clustering
- Large range of satellite fractions
- Satellites positioned with either NFW profile or particles
- No smearing / Gaussian smearing / realistic smearing





Rescaling Cosmology

- Method of Mead & Peacock 2014
- Steps to method:
  - Scale position/mass/redshift to produce correct halo mass function
  - Displace haloes using Zel'dovich approximation to produce correct P(k)
  - Modify internal structure of haloes (change concentrations)
  - Scale halo velocities
- To test method, rescale MultiDark Planck2 simulation to Millennium WMAP1 cosmology (simulations have same FOF mass definition, which is different to OuterRim)

Scaling σ(M)

- Scale original simulation cosmology to new target cosmology by matching σ(M)

- Scale comoving positions by factor s $L' = sL$

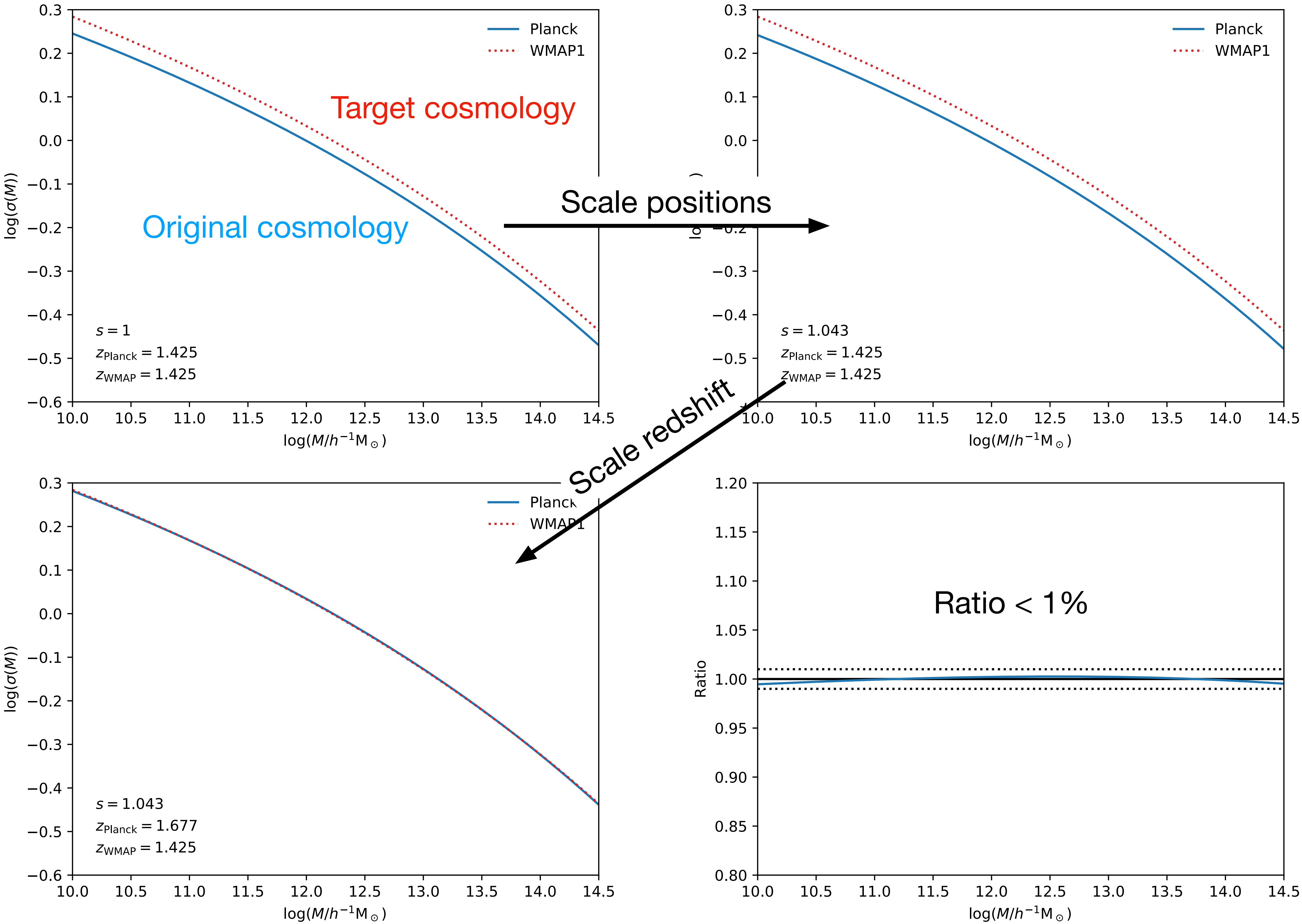
- Since $M = \frac{4}{3}\pi R^3 \bar{\rho}$, scale masses by $M' = s_\mathrm{m} M; \quad s_\mathrm{m} \equiv s^3 \frac{\Omega'_\mathrm{m}}{\Omega_\mathrm{m}}$

- Relabel redshift of simulation snapshot

- Minimize

$$\delta^2_\mathrm{rms}(s, z \mid z') = \frac{1}{\ln(R'_2/R'_1)} \int_{R'_1}^{R'_2} \frac{\mathrm{d}R}{R} \left[1 - \frac{\sigma(R/s, z)}{\sigma'(R, z')}\right]^2$$

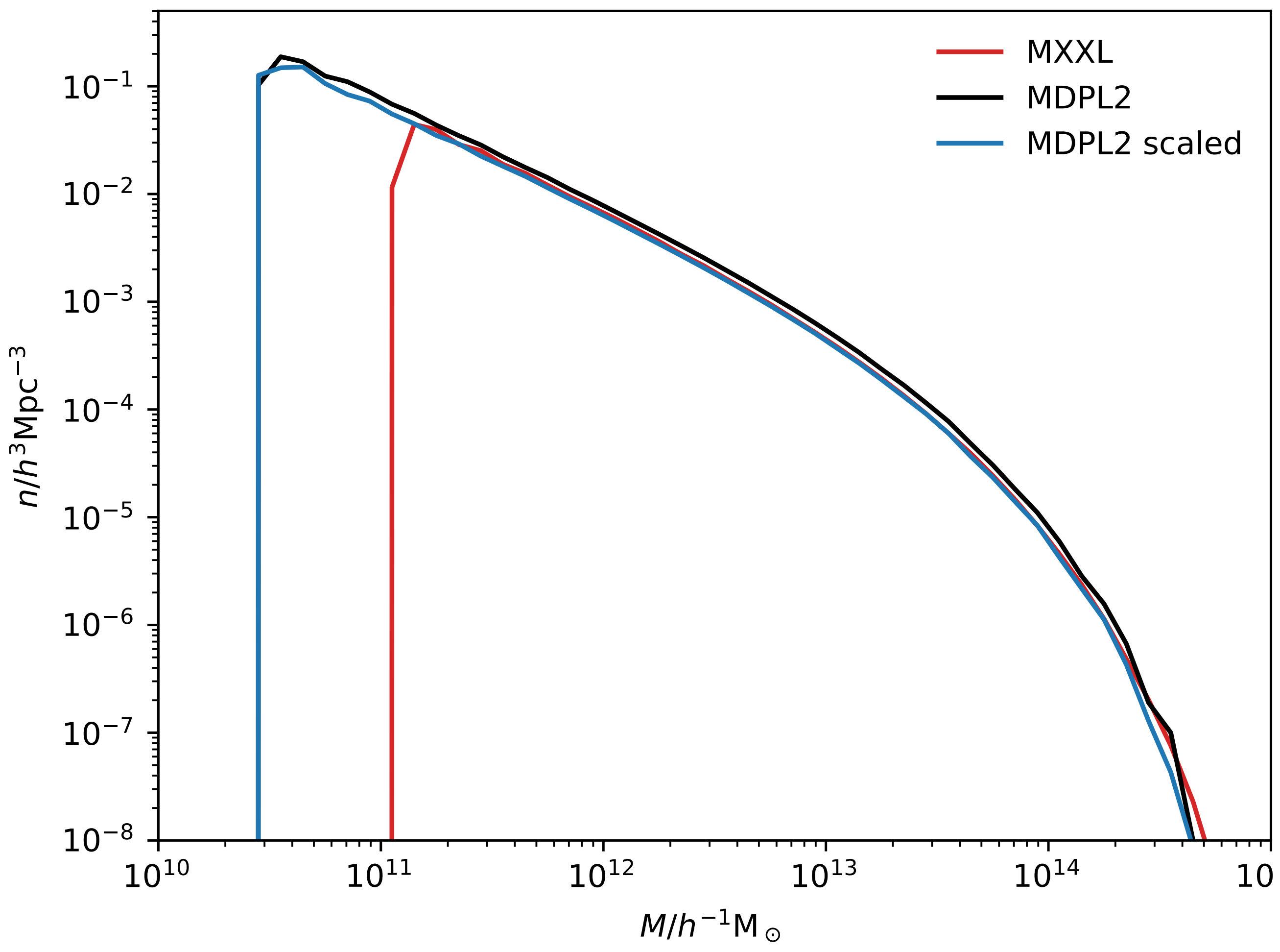
Scaling σ(M)

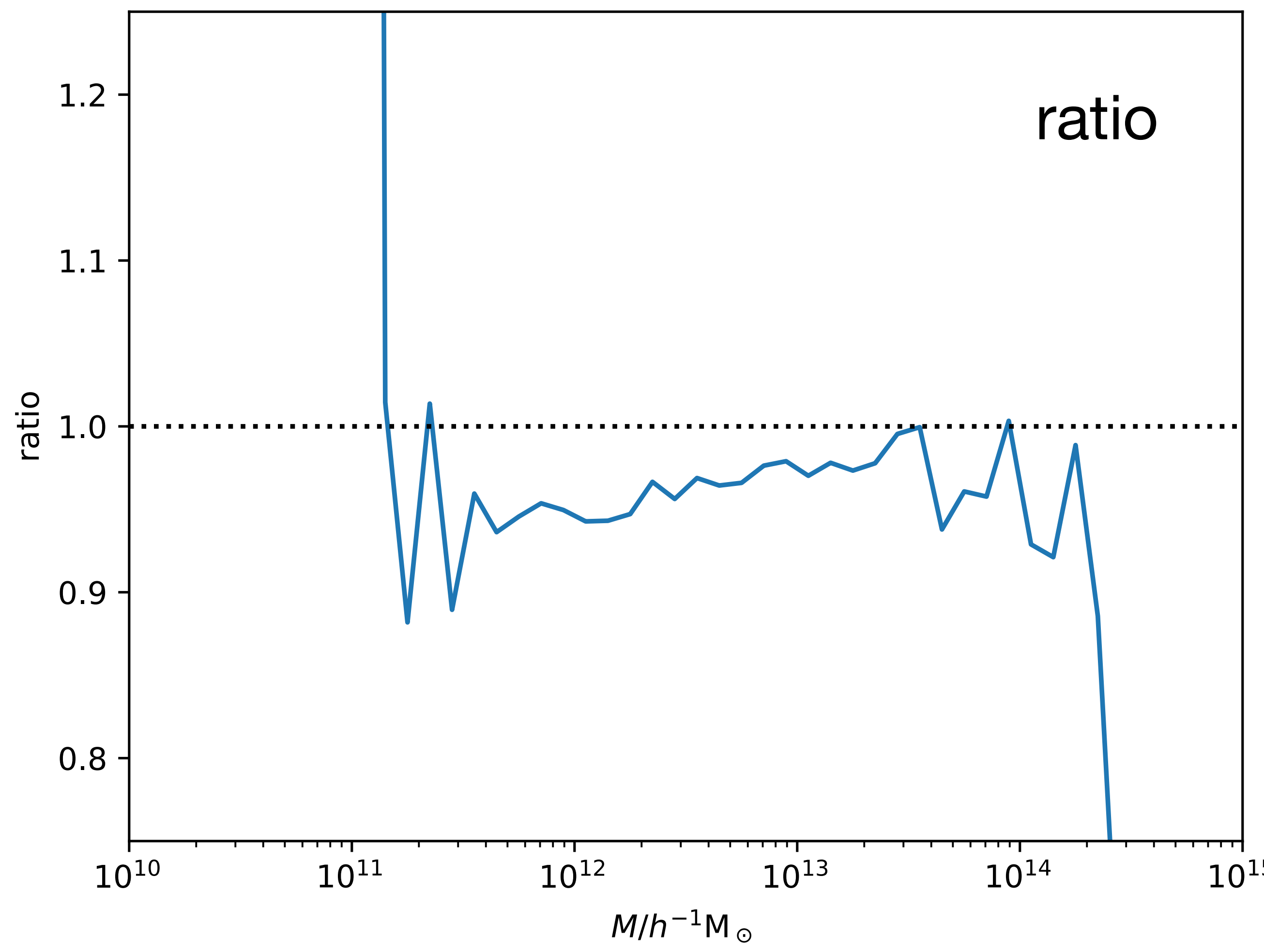


Planck
WMAP1
Target cosmology
Original cosmology
s = 1
z_Planck = 1.425
z_WMAP = 1.425
log(σ(M))
log(M/h^-1 M_⊙)
Scale positions
s = 1.043
z_Planck = 1.425
z_WMAP = 1.425
Scale redshift
s = 1.043
z_Planck = 1.677
z_WMAP = 1.425
Ratio < 1%
Ratio

N-body Mass Function

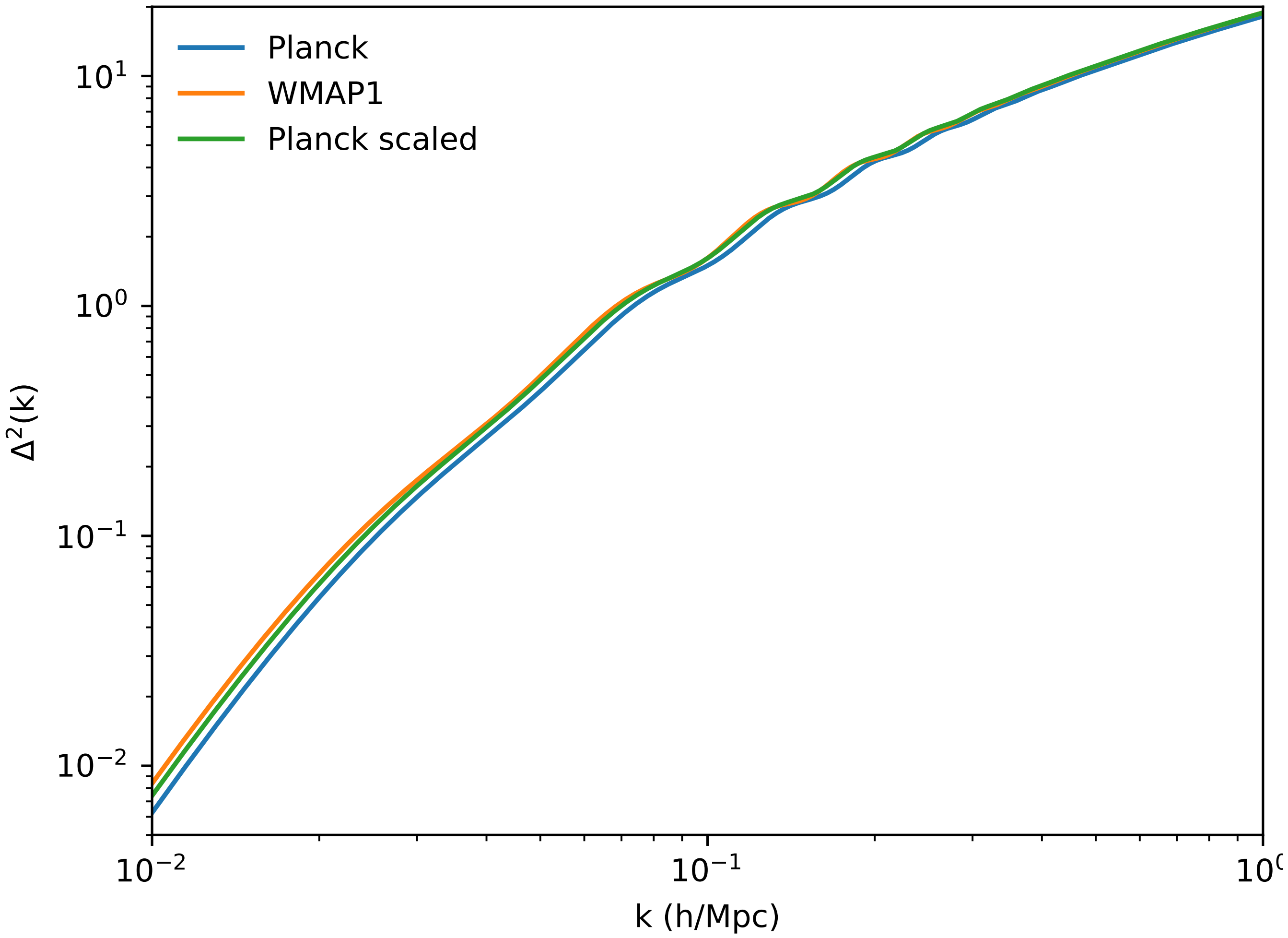
- MDPL2 scaled to MXXL

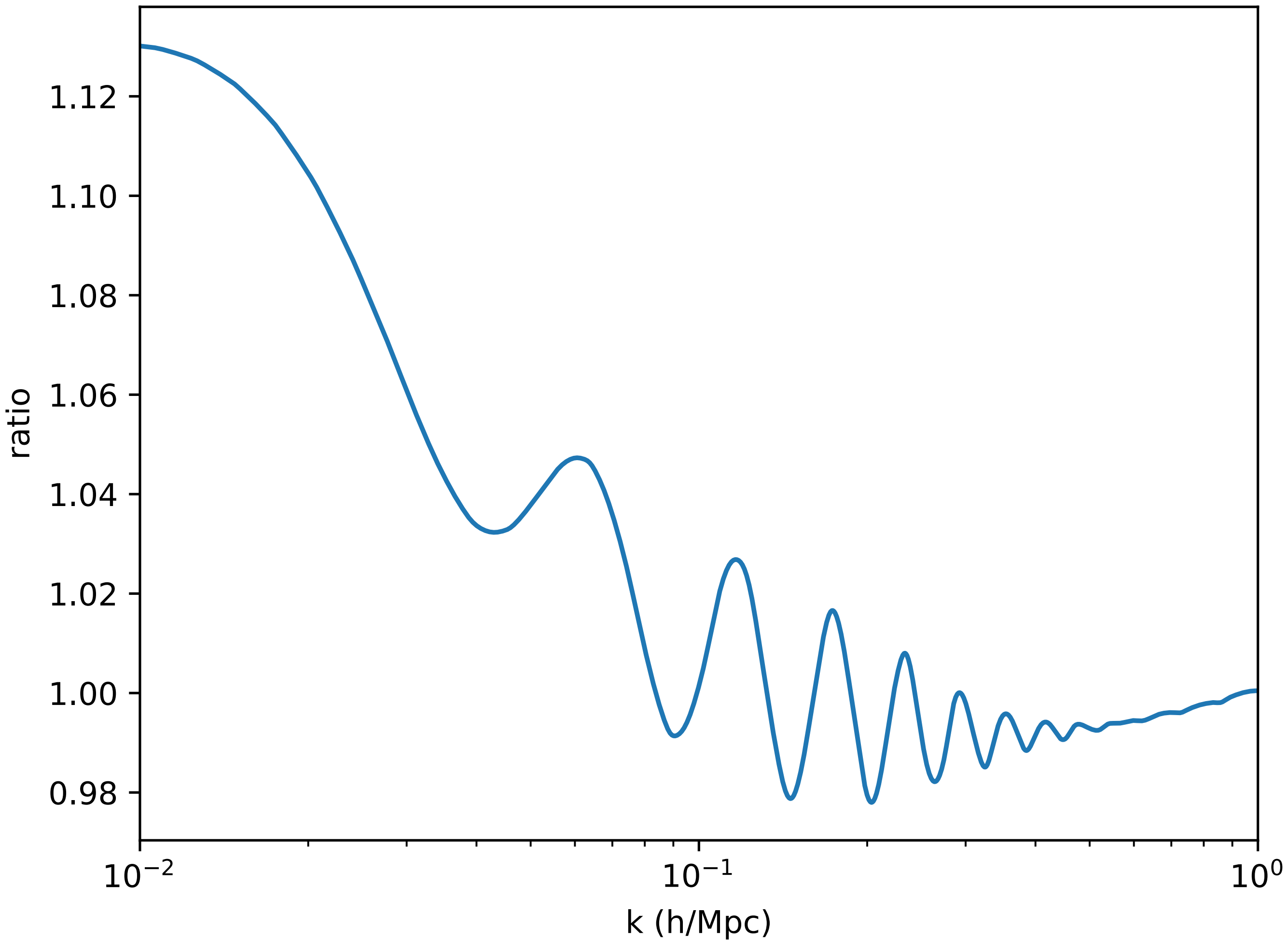




Linear Power Spectrum

- Linear power spectrum after scaling



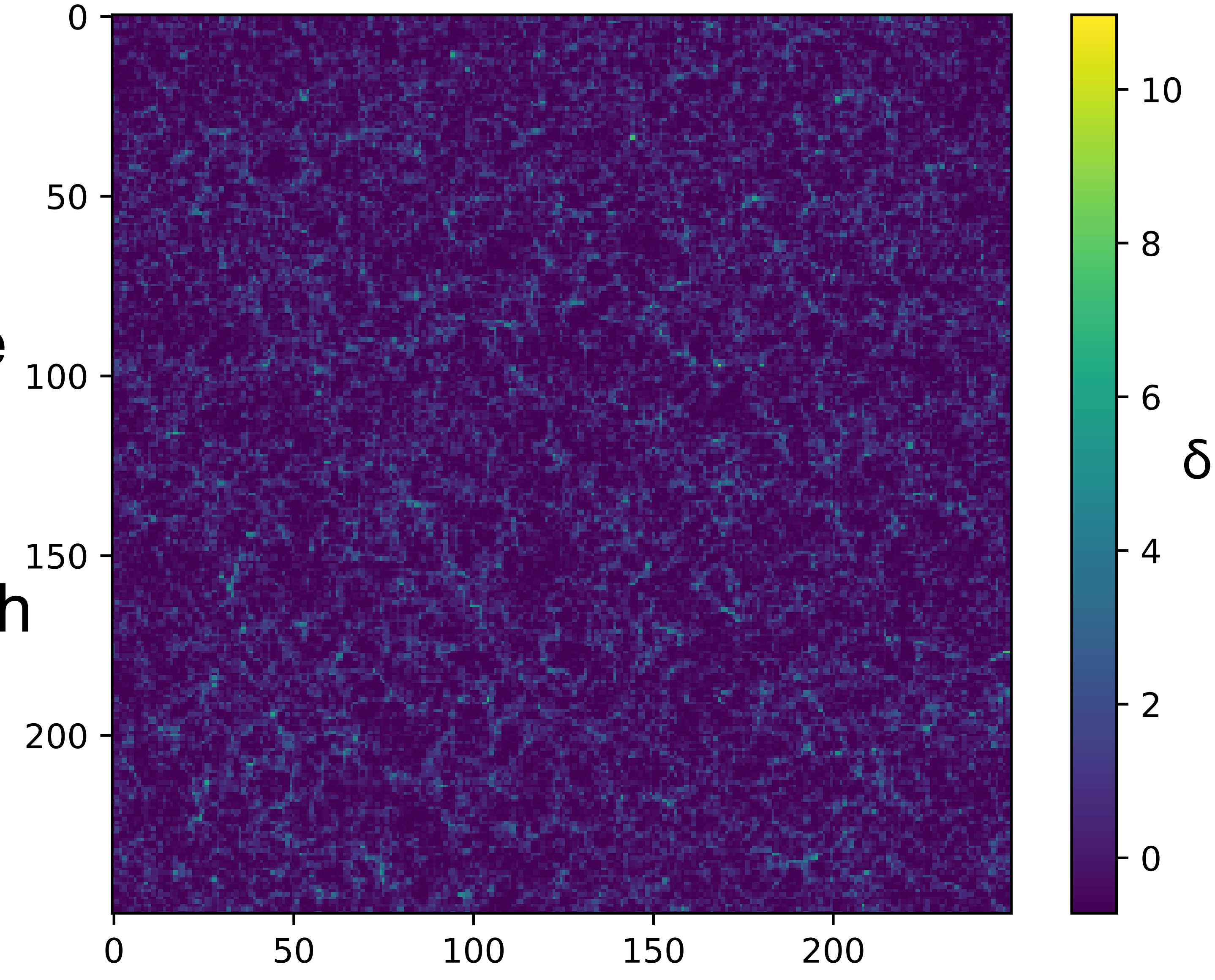


Displacing halo positions

- Displacement field moves particles from their initial to final positions $\boldsymbol{x} = \boldsymbol{q} + \boldsymbol{f}$
- Related to matter over density $\delta = -\nabla \cdot \boldsymbol{f}$
- In Fourier space $\boldsymbol{f}_{k} = -i \frac{\delta_{k}}{k^2} \boldsymbol{k}$.
- Change in f due to different cosmology $$\delta \boldsymbol{f}_{k'} = \left[\sqrt{\frac{\Delta'^2_{\text{lin}}(k', z')}{\Delta^2_{\text{lin}}(sk', z)}} - 1 \right] \boldsymbol{f}_{k'}$$
- Adjust positions by $\boldsymbol{x}' = \boldsymbol{x} + \delta \boldsymbol{f}$
- To get right mass-dependent bias, multiply displacement by b(M)

Density Field

- MDPL2 (z=1.425) scaled to MXXL cosmology (z=1.66, with s=1.05, s_m=0.94)
- Density field calculated on 250^3 grid (Each cell ~ 4 Mpc/h)
- Effective bias b=1.39
- Plotted in slice 1 cell thick
- Smoothed on non-linear scale (R_{nl} where $\sigma(R_{nl},z) = 1$) using a Gaussian filter
- At this redshift, R_{nl} = 1.8 Mpc/h

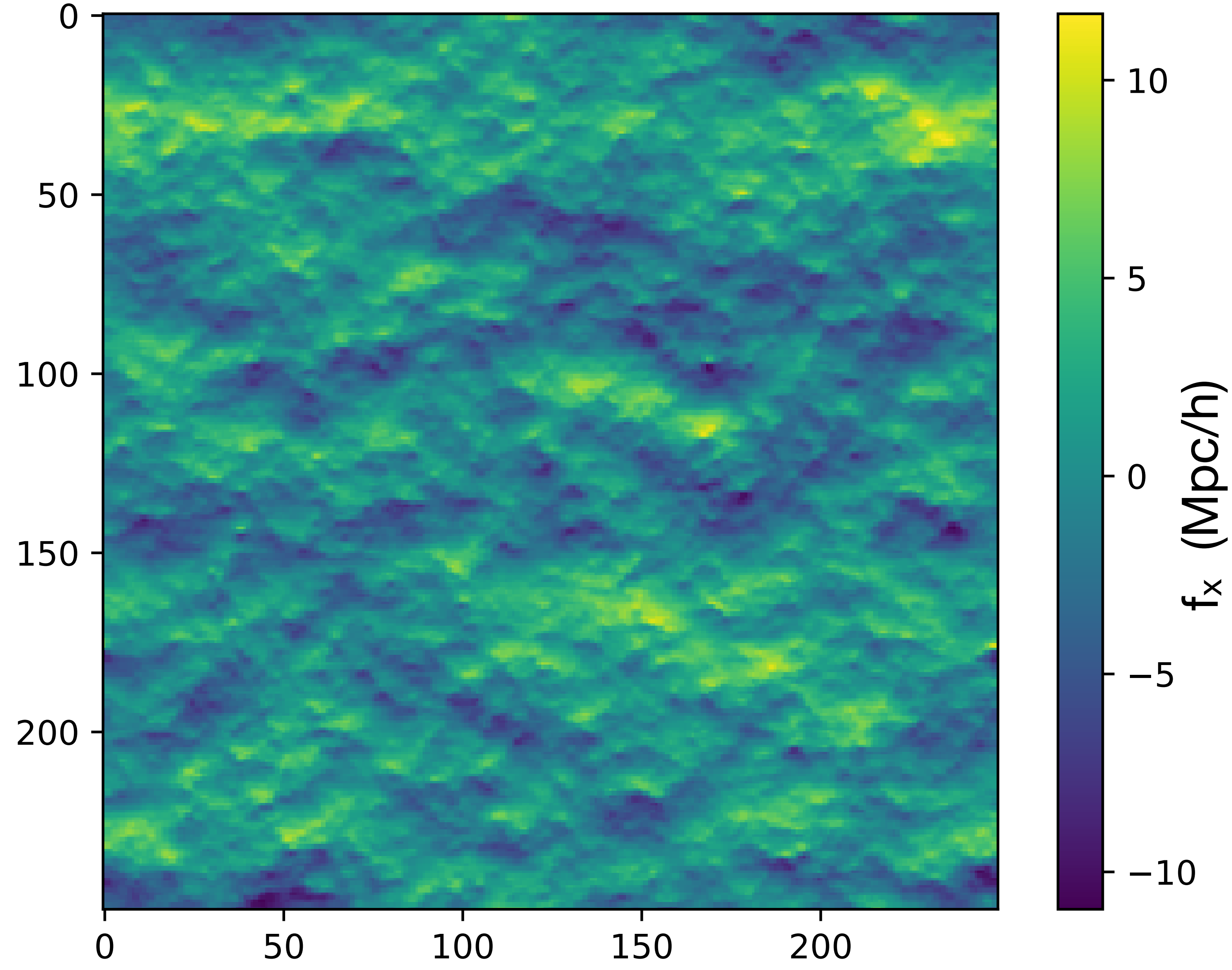


Displacement Field

- x-component of displacement field
- Adjusted to have correct theoretical variance

$$\boldsymbol{f}_{\boldsymbol{k}} = -i \frac{\delta_{\boldsymbol{k}}}{k^2} \boldsymbol{k}.$$

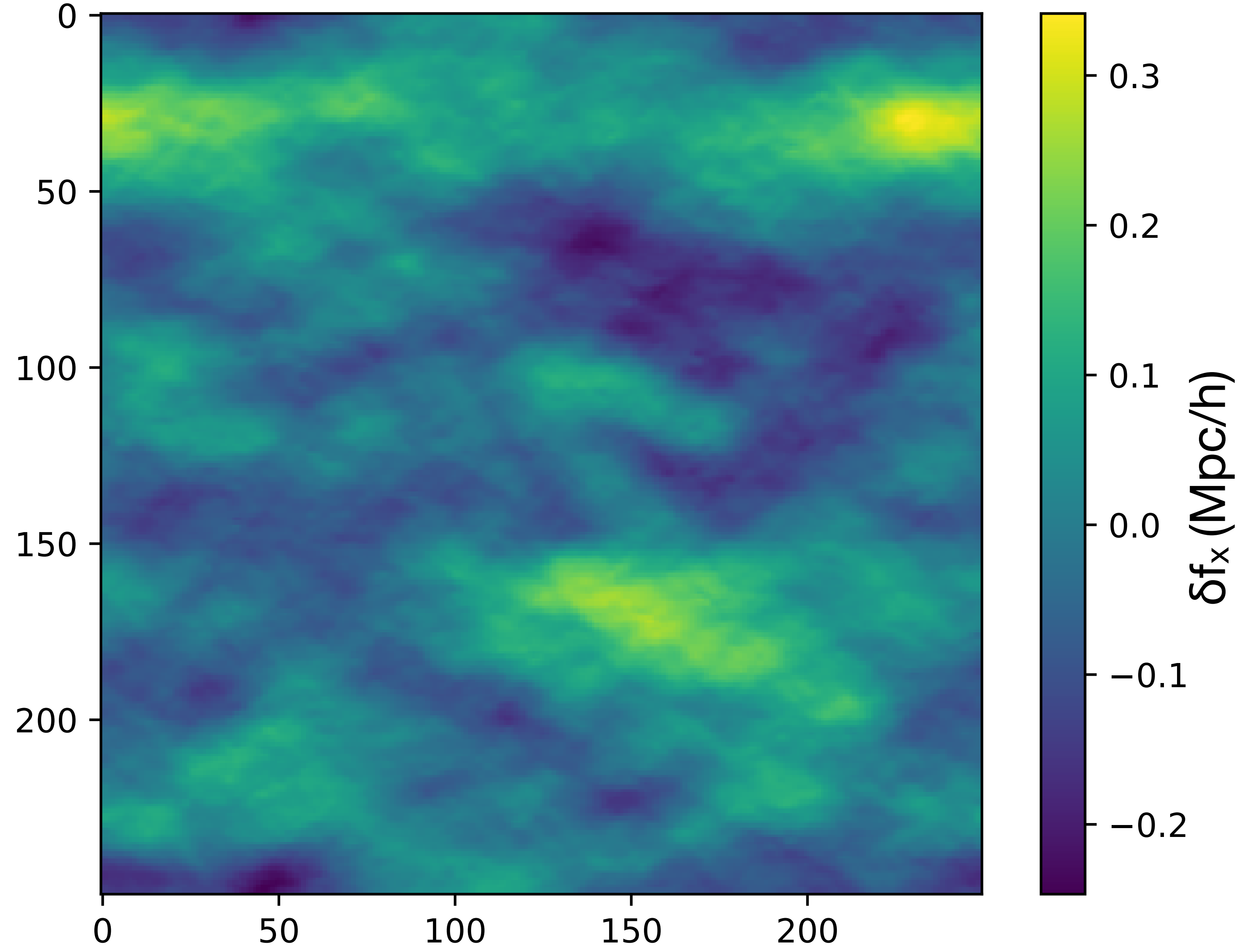
$$\sigma_f^2(R_{\rm nl}) = \frac{1}{3} \int_{k_{\rm box}}^{\infty} \frac{e^{-k^2 R_{\rm nl}^2} \Delta_{\rm lin}^2(k)}{k^2} d \ln k$$



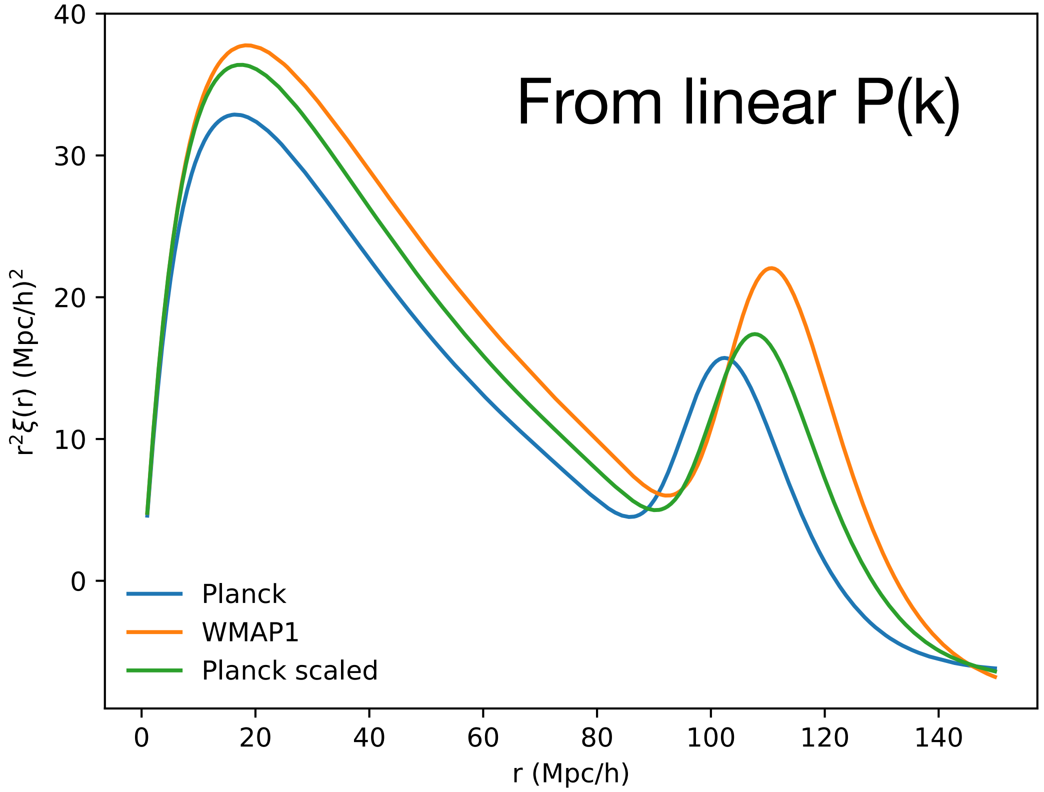
Differential Displacement

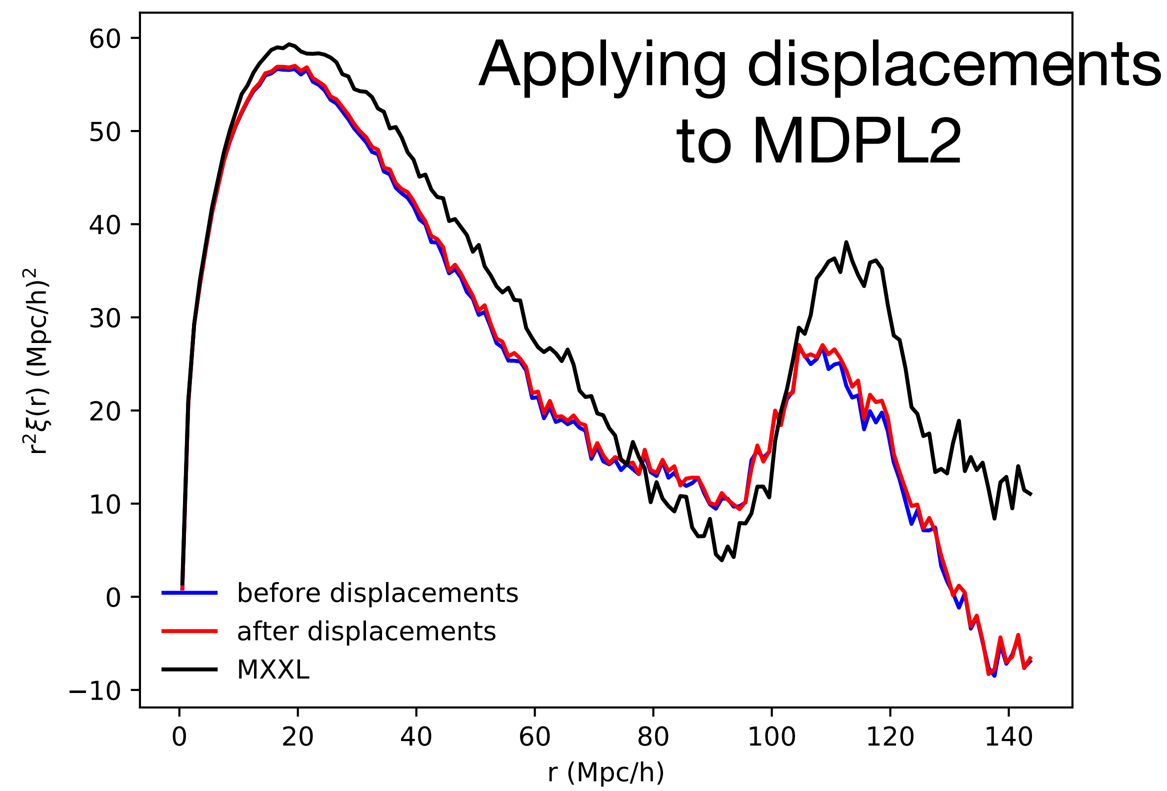
- x-component of differential displacement field

$$\delta f_{k'} = \left[\sqrt{\frac{\Delta'^2_{\text{lin}}(k', z')}{\Delta^2_{\text{lin}}(sk', z)}} - 1 \right] f_{k'}$$

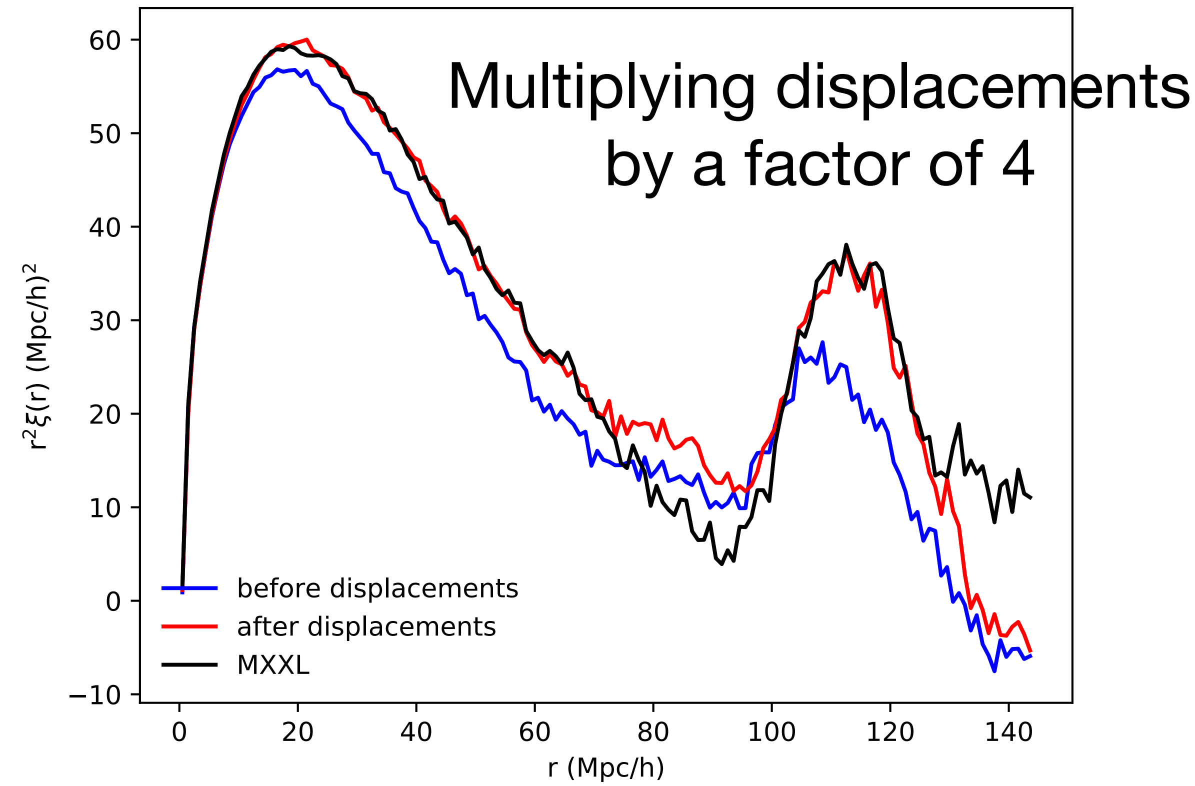


Clustering After Displacements





- Displacements are correct, but a factor of 4 too small!



Where is this factor from?

- All units consistent (e.g. positions are comoving Mpc/h)
- Double checked $P_{lin}(k,z)$, $\Delta_{lin}^2(k,z)$, $\sigma(M,z)$, etc
- No factors of 2π from FFTs
- Doesn't depend on grid size
- When scaling is done at z=0, displacements are still off by a factor of ~4
- Displacement field theoretical variance calculation correct
- Without scaling, the variance in the displacement field at z=0 in good agreement with theoretical variance
- But at z=1.425, they differ by a factor ~ 1.4