Fast generation of ensembles of cosmological N-body simulations via mode-resampling

Michael D. Schneider

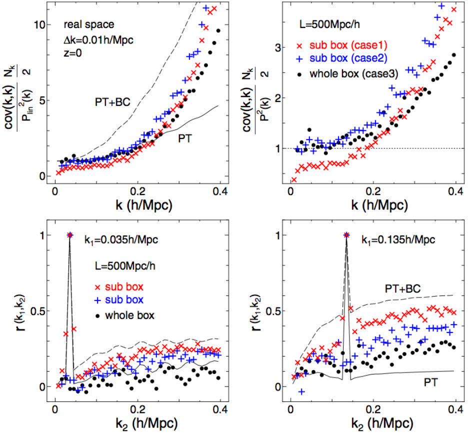
LLNL

December 16-17, 2010

In collaboration with: Istvan Szapudi, Shaun Cole, Carlos Frenk

Motivation: power spectrum covariance

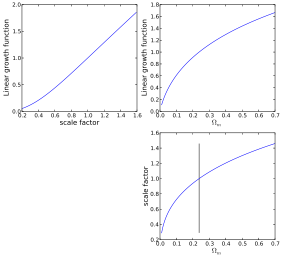
- Cosmological parameter estimation from surveys of LSS require knowledge of the nonlinear power spectrum covariance.
- Takahashi et al. (2009) use 5000 simulations to estimate the matter power spectrum covariance.
    - Nonlinearity of density field degrades S/N for power spectrum amplitude by ~ 4 (Neyrinck & Szapudi 2007, Rimes & Hamilton 2006)
    - PT or HM not accurate enough
- "Beat–coupling" requires independent mocks (Hamilton et al. 2006)



Adding large-scale perturbations

Related work:

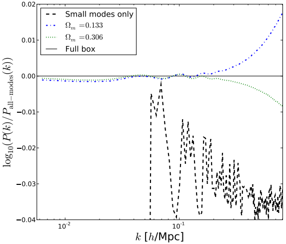
Little, Weinberg, Park (1991)
Tormen & Bertschinger (1996)
Cole (1997)



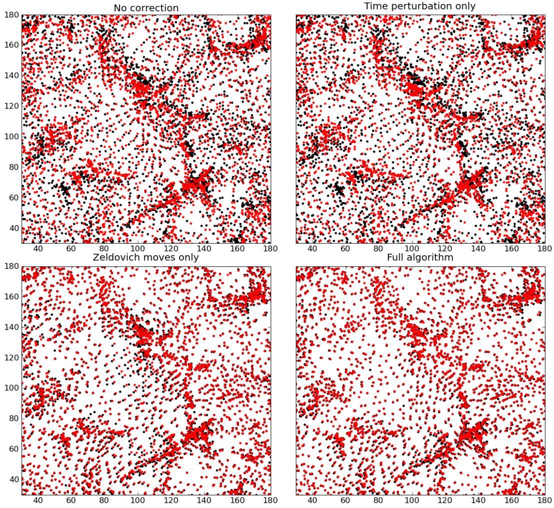
Two dominant effects of long-wavelength perturbations:

1. sub-volumes expanded or compressed (Zeldovich move)
2. sub-volumes gravitationally evolve with different effective background matter density (time-perturbation)

$$D(a', \Omega_0) \approx D(a, \Omega_0(1 + \delta_L(\mathbf{x}, a)))$$

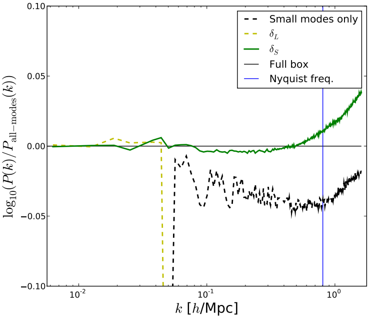


Full algorithm for adding large-scale modes

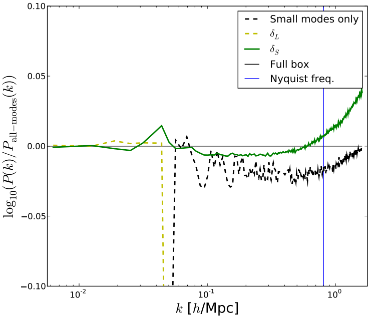


1. Generate ICs with zero power for $k < k_{\text{thresh}}$.
2. Run N-body sim., saving snapshots at closely-spaced times and into the future.
3. Draw large–scale Fourier modes from Gaussian distribution.
4. Apply Zeldovich move evaluated at $z = 0$.
5. Use large–scale modes to calculate $x' \to \Omega'_m \to a'$.
6. Use saved snapshots to find particle positions at a'.

Nonlinear power spectrum recovery

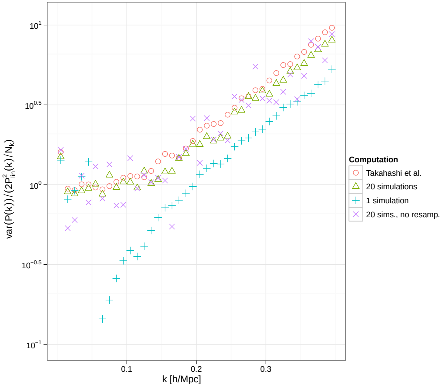


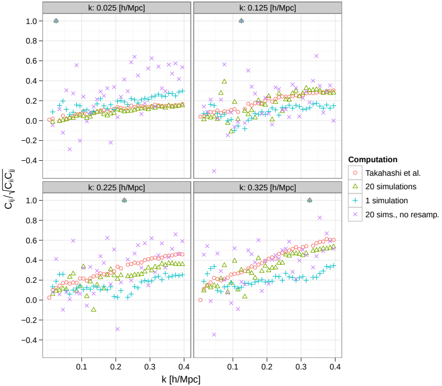
(a) SCDM



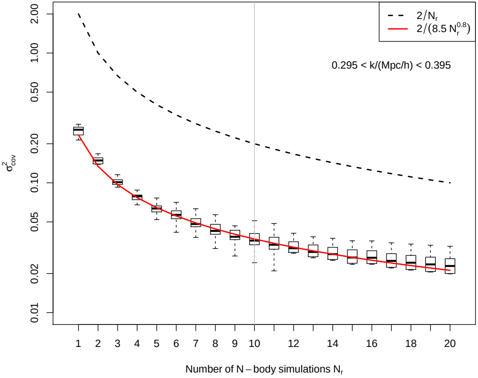
(b) ΛCDM

Power spectrum covariance estimates





Preliminary



Extrapolating:

~ 385 of our simulations equivalent to 1000 “standard” simulations.

Conclusions

- Method to resample large–scale modes
  - Accurate nonlinear power spectrum
  - Introduce non-zero cross-covariance
- Improve convergence rate of power spectrum covariance estimates.
  - Useful for generating mocks for parameter estimation.
- Apply to rescaling simulations for new input parameters (following Angulo & White 2009)?
- Include dynamical effects from modes larger than the simulation box size?