Theoretical Issues Facing Weak Lensing Analyses

Discussion

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Theory and Analysis

- N-body simulations
  - Ray tracing vs Born
  - Numerical convergence/computational cost
  - Grids and interpolation
- Extra physics
  - How (much) will this limit us?
  - Approximate treatments
- Metrics to compare theory and data
  - For overall power 2-pt shear $\xi(\theta)$ seems optimal
  - What is best measure of non-Gaussianity?
  - Radical compression of huge amount of low-S/N data to a few high-S/N objects
- Intrinsic alignments and source contamination
  - How do we deal with this in D/A?

Tests of the MLP

With Chris Vale we have made extensive tests of the MLPA and its convergence properties:

- **The effect of border discontinuities**
- **The "ray-plane perpendicular" approximation**
- **The first fully 3-d ray tracing protocol**
- **Time evolution effects**
- **Number of lens planes necessary**
- **Numerical resolution issues**
- **Test common analytic approximations**

Vale & White (2003)

Bottom line: MLP is good to at least a few percent in the power spectrum; the limiting computational cost is the generation of N-body simulations.

Advantages and disadvantages of maps

- When simulating WL can choose to work with just the power spectrum, or with simulated maps.
- Advantages
  - —Can test/refine D/A algorithms
  - —Can look at higher order functions
  - —Allow cross-correlation studies etc.
- Disadvantages
  - —Contain extra numerical artifacts
  - —Limited field of view (<100 sq. deg./map)

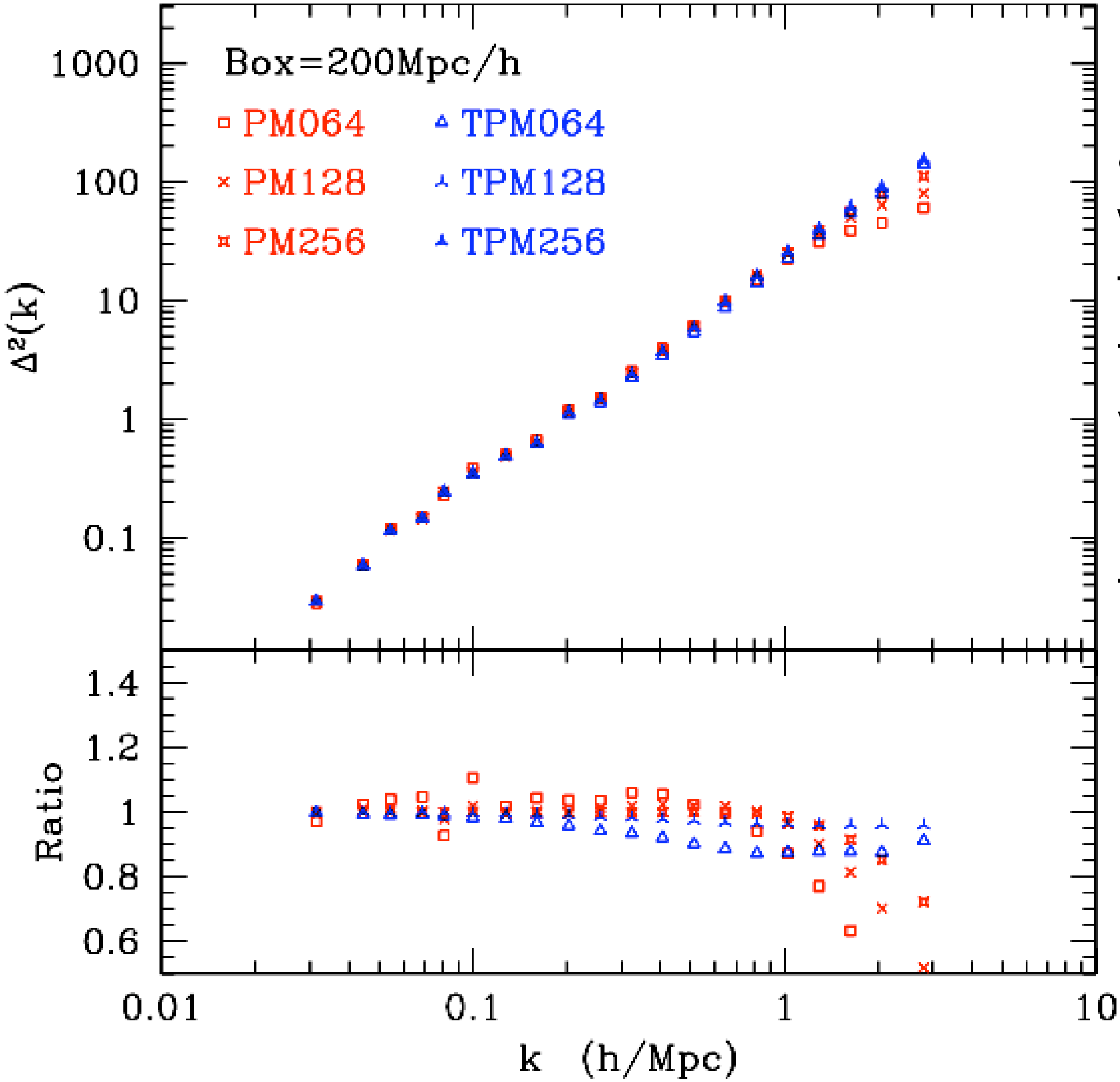
Computational cost

Almost all of the CPU cycles are spent on the N-body simulation, which is also the major accuracy driver.

There are, basically, two kinds of simulations: high and low force resolution (PM) which differ in cost by ~x10.

Low resolution (PM)	**High resolution (TPM)**
128^3 ~ 10 CPU hours	**128^3 ~ 100 CPU hours**
256^3 ~ 100 CPU hours	**256^3 ~ 1,000 CPU hours**
512^3 ~ 1,000 CPU hours	**512^3 ~ 10,000 CPU hours**
1024^3~10,000 CPU hours	**1024^3~ 100,000 CPU hours**

Numerical convergence

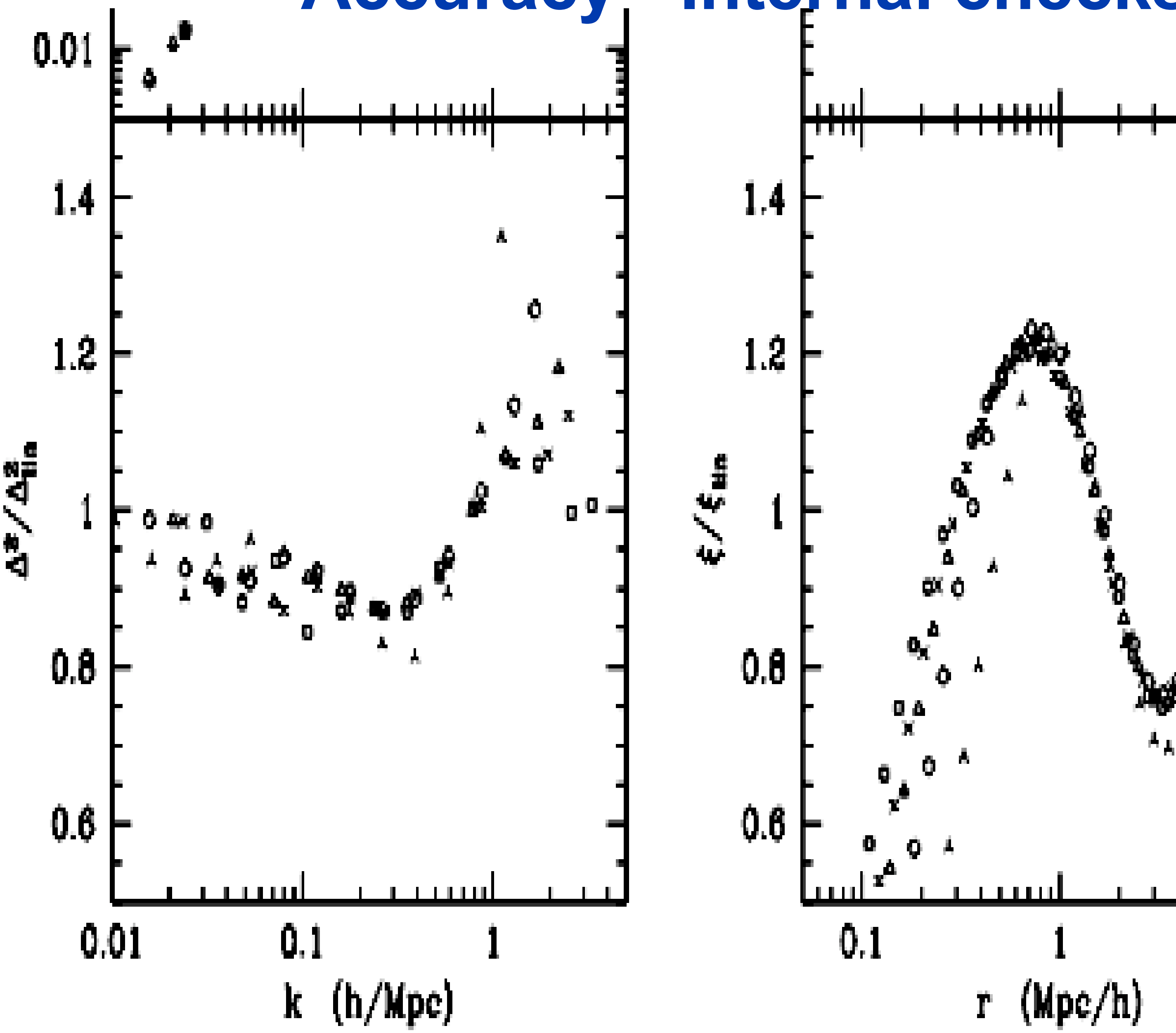


Increased resolution and particle number, with low-*k* modes fixed between runs to eliminate sample variance.

PM - low force resoln.

TPM- high force resoln.

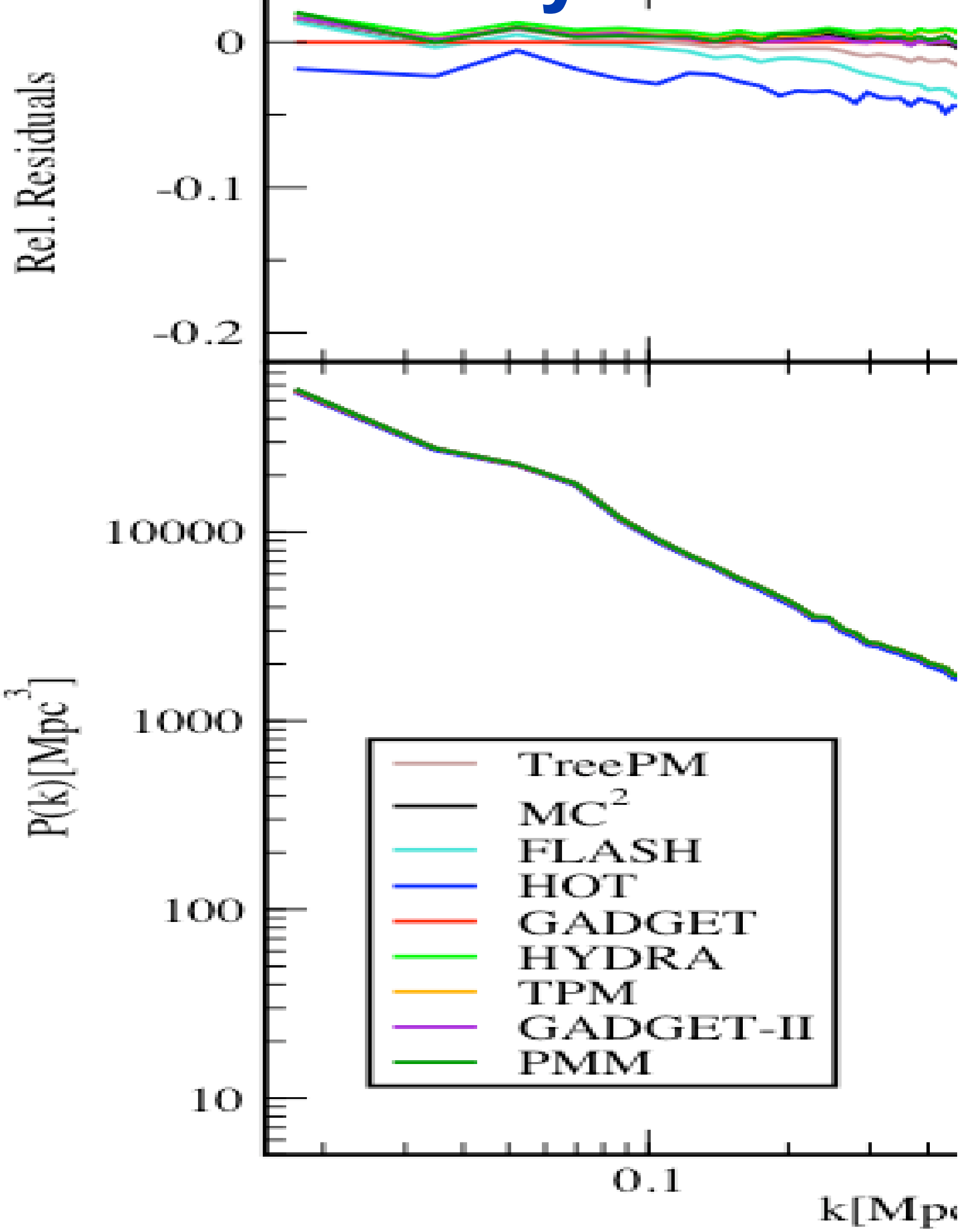
Accuracy - Internal checks



Gravity is scale-free, so a power-law *P(k)* in an Ω_m=1 universe should evolve self-similarly.

Example: 128^3 TPM simulation.

Accuracy - currently demonstrated

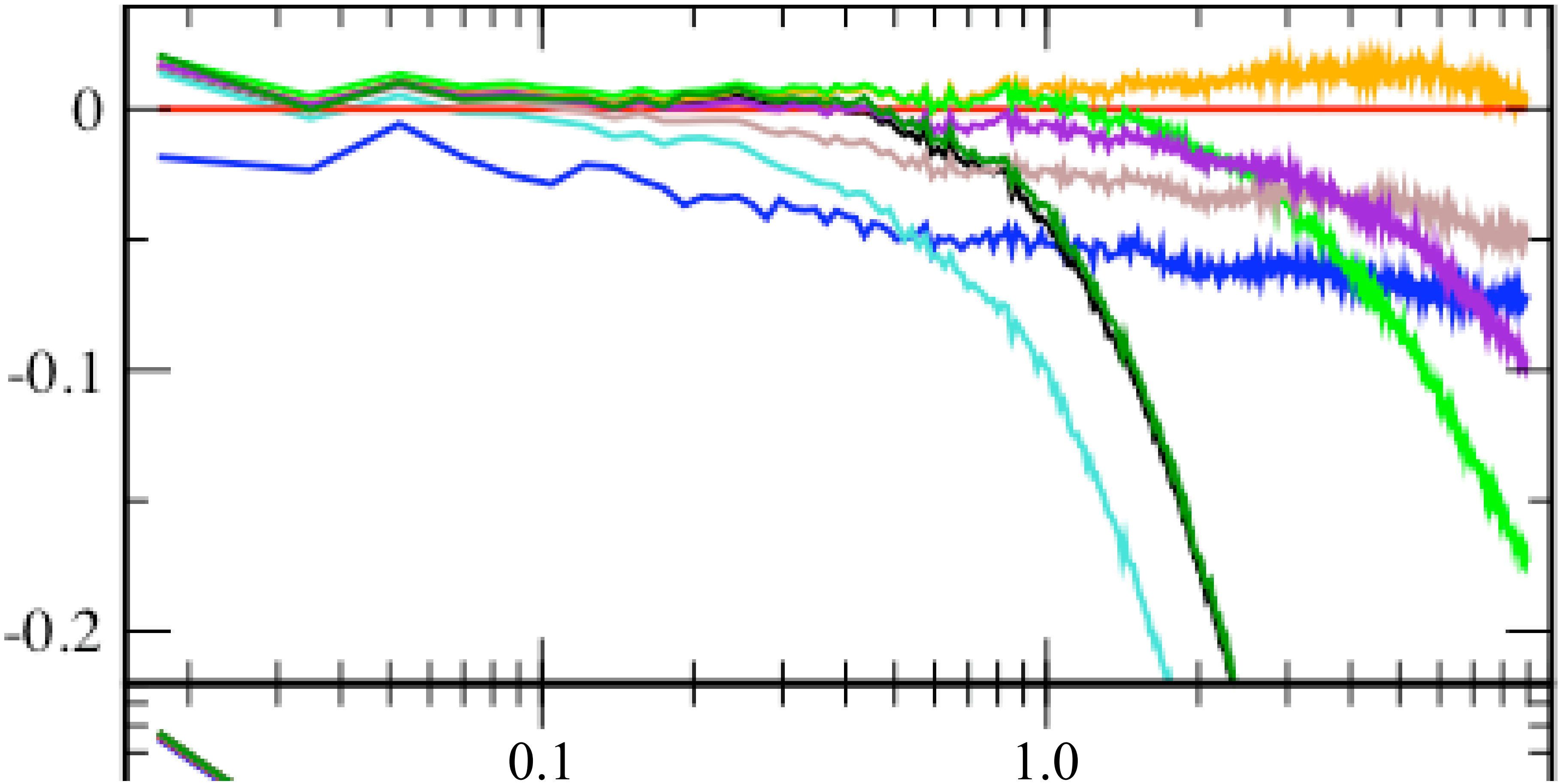


Code comparison - updated from Heitmann et al. (2005).

Cosmological volume: 256Mpc/h, 256^3 particles.

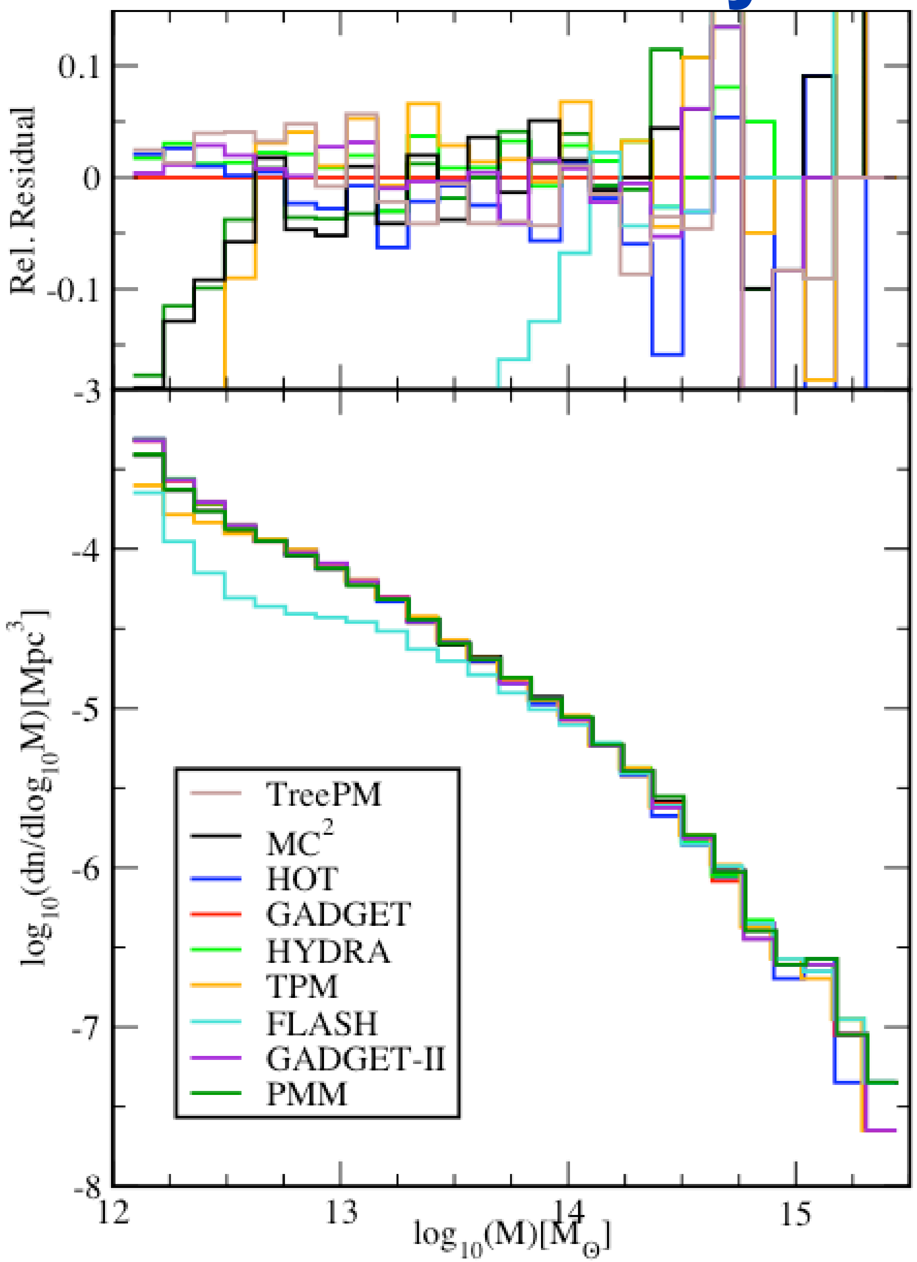
All codes started from the same ICs and analyzed with the same *P(k)* codes.

Accuracy - zoom in



Current accuracy is a few percent among the better codes.

Accuracy - mass function



For many measurements the mass function is also important.

Update of Heitmann et al. (2005)

Adding Physics

- If numerical effects can be bought under control, the next issue is correctly modeling the appropriate physics.
- On small scales non-gravitational forces come in to play.
  - —Baryonic pressure and cooling affect C_l at % level beyond l~1000-3000.
    - Given an N-body simulation can compute potential and hence equilibrium distribution of hot gas (given equation of state).
    - Can use adiabatic contraction models to approximate the effects of cooling baryons
      - **But Kazantzidis et al.?**

Meeting ground between theory & observation

- Getting cosmology from weak lensing requires us to compare exquisite data with reliable theory.
- What are the right statistics with which to make this comparison?
- Overall power level
  —Two-point shear correlation functions
- Non-Gaussianity
  —Three-point functions
  —Aperture mass statistics, generalized skewness
  —Peak statistics

Intrinsic alignments

- Lots of numerical and analytic arguments
  - Croft & Metzler (2000); Heavens, Refregier & Heymans (2000); Catelan, Kamionkowski & Blandford (2000); Lee & Pen (2000, 2001); Crittenden et al. (2001); Mackey, White & Kamionkowski (2002); Jing (2002); etc
  - Mostly untrustworthy!
- Very few measurements
- Several ways of suppressing intrinsic alignment effects
  - King & Schneider (2002, 2003); Heymans & Heavens (2003); Heymans et al. (2004); Takada & White (2004); King (2005)
- Possible "extra" effects: GI correlation
  - Hirata & Seljak (2004)
  - Vanishes for $\boldsymbol{\varepsilon \sim L^2}$ as predicted by tidal torque theory