UNIVERSITY OF CAMBRIDGE

Measuring the Bispectrum in Galaxy Surveys

A comparison of DM codes

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Outline

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  - Statistics
- LSS Bispectrum
  - MODAL-LSS
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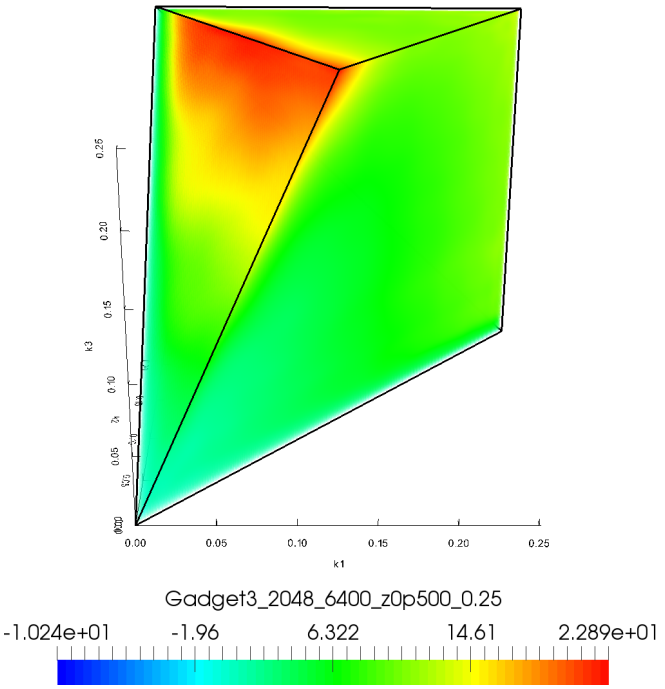
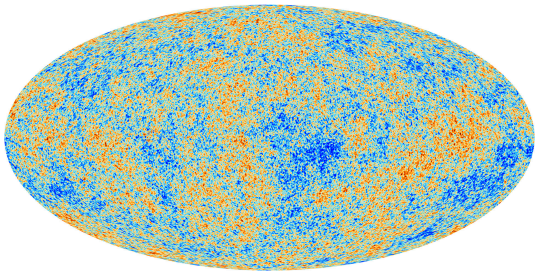
- Conclusions and Future Work

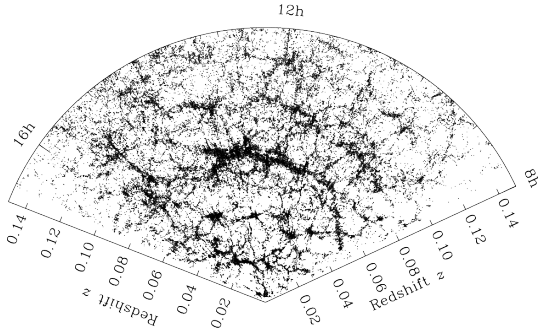


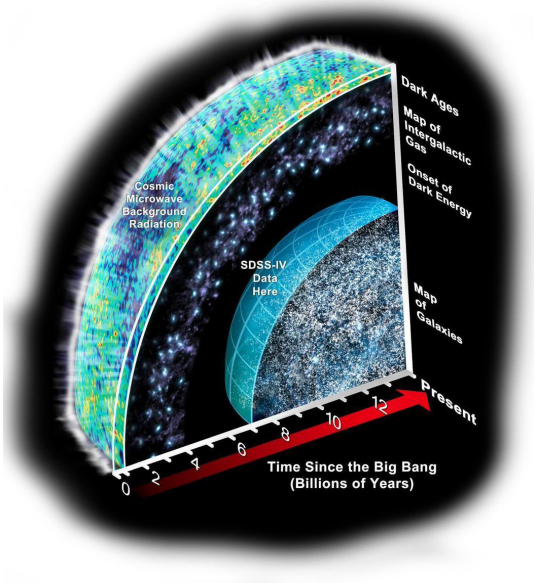
Introduction

CMB and LSS



CMB	LSS
2D dataset	3D dataset
Linear	Non-linear



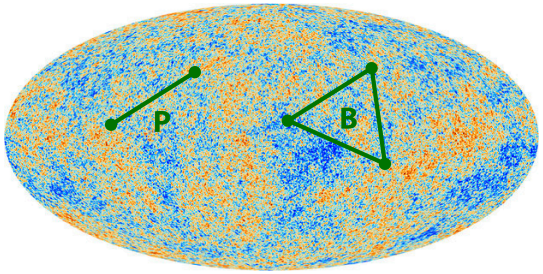


Both equally important:

Complementarity of scales

Cross-correlation

Statistics

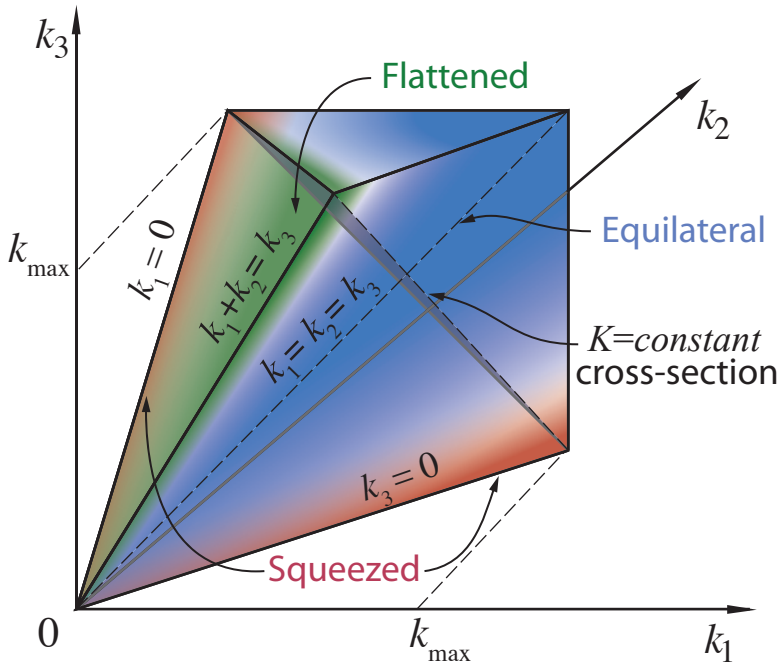


- Power spectrum, or two-point correlation function
- At small scales the bispectrum surpasses the power spectrum in signal-to-noise
  - Better at tracing non-linear evolution of structure
  - Break degeneracies in parameter space, e.g. bias
  - Investigate primoridial non-Gaussianity
- We have developed a **fast** code (MODAL-LSS) for reconstructing the **full** bispectrum of cosmological simulations (Schmittfull et al. 2013)

LSS Bispectrum

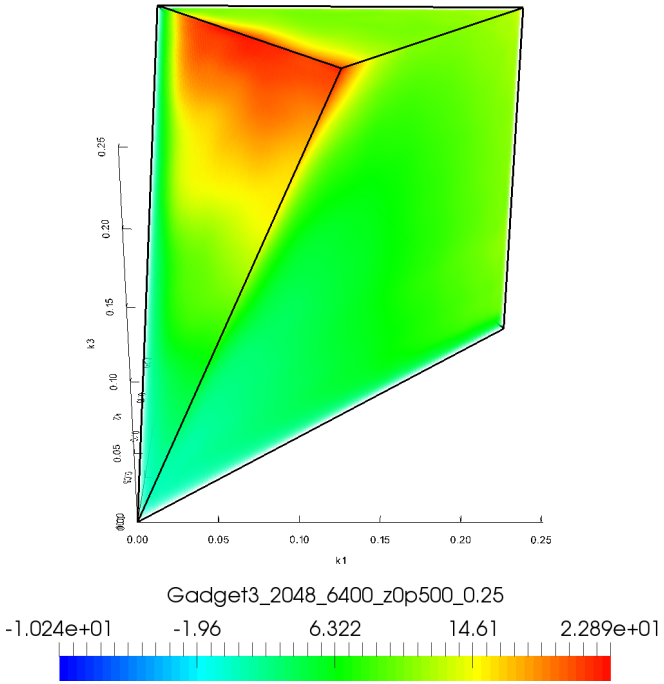
LSS Bispectrum

Bispectrum tetrapyd cut in half:



Different shapes have strongest signals in different parts of the tetrapyd

Simulation bispectrum:



The morphology gives us qualitative information about the bispectrum shape

MODAL-LSS

- General bispectra computationally intractable
- Expansion of signal-to-noise (SN) weighted bispectrum in separable basis:

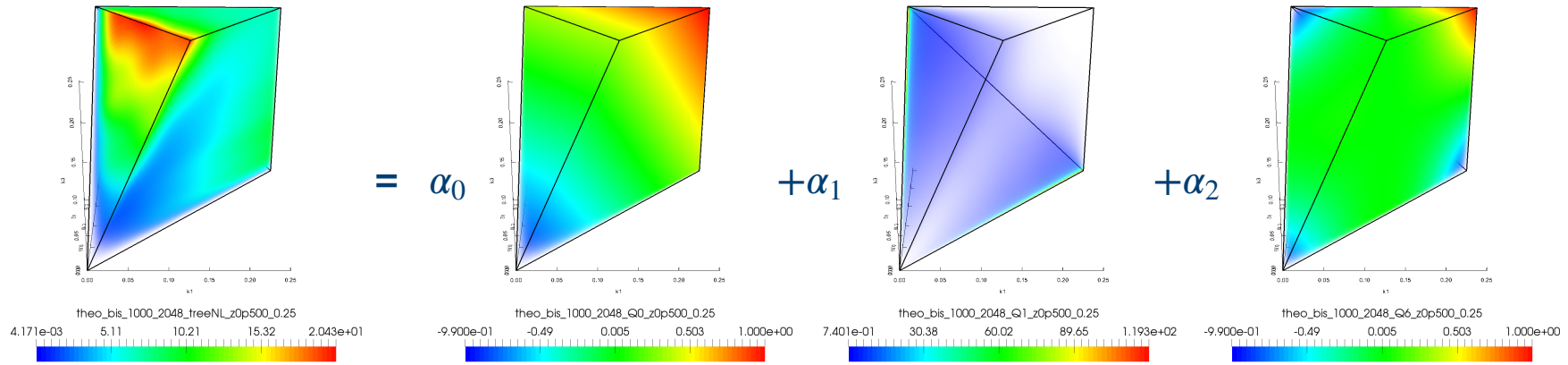
$$\sqrt{\frac{k_1 k_2 k_3}{P(k_1)P(k_2)P(k_3)}} B^{th}(k_1, k_2, k_3)$$
$$\approx \sum_{n}^{n_{max}} \alpha_n^Q Q_n(k_1/k_{max}, k_2/k_{max}, k_3/k_{max})$$

- The basis functions are symmetrised products over polynomial functions:

$$Q_n(x, y, z) \equiv q_{\{r}(x) q_s(y) q_{t\}}(z)$$

  - Reduces bispectrum estimation from 3D problem to 1D problem
- Can use O(1000) modes for highly accurate reconstruction

MODAL-LSS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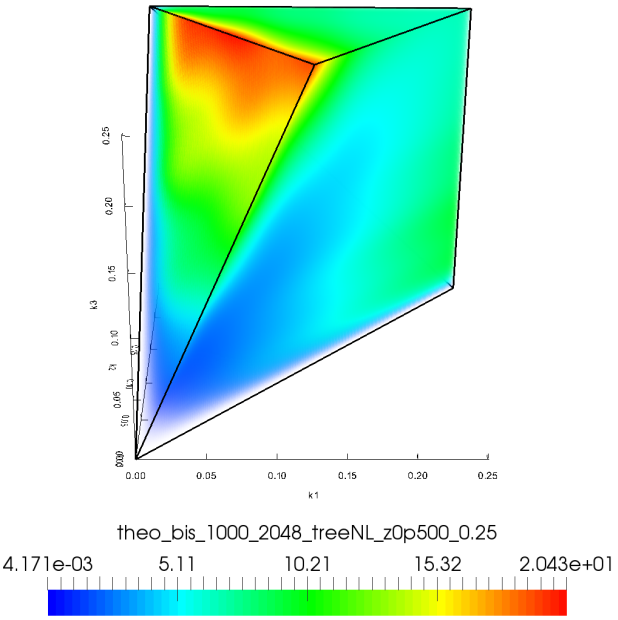
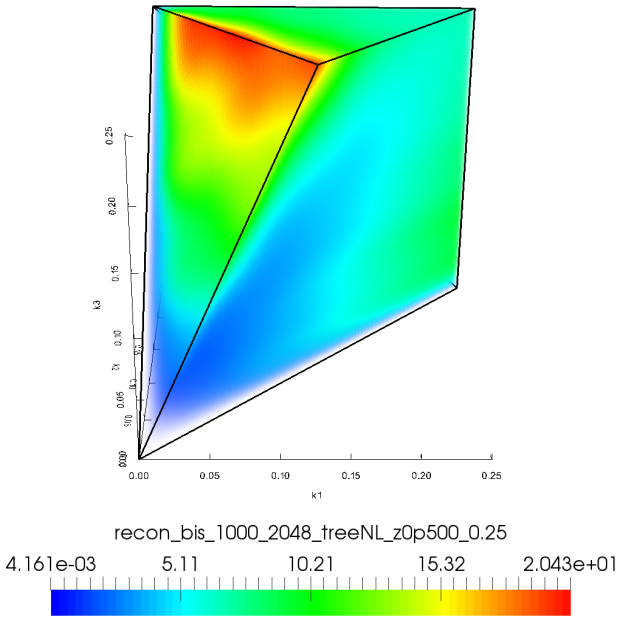
4.171e-03 5.11 10.21 15.32 2.043e+01
= α_0
theo_bis_1000_2048_Q0_z0p500_0.25
-9.900e-01 -0.49 0.005 0.503 1.000e+00
$+\alpha_1$
theo_bis_1000_2048_Q1_z0p500_0.25
7.401e-01 30.38 60.02 89.65 1.193e+02
$+\alpha_2$
theo_bis_1000_2048_Q6_z0p500_0.25
-9.900e-01 -0.49 0.005 0.503 1.000e+00
+……

Bispectrum Theory Validation

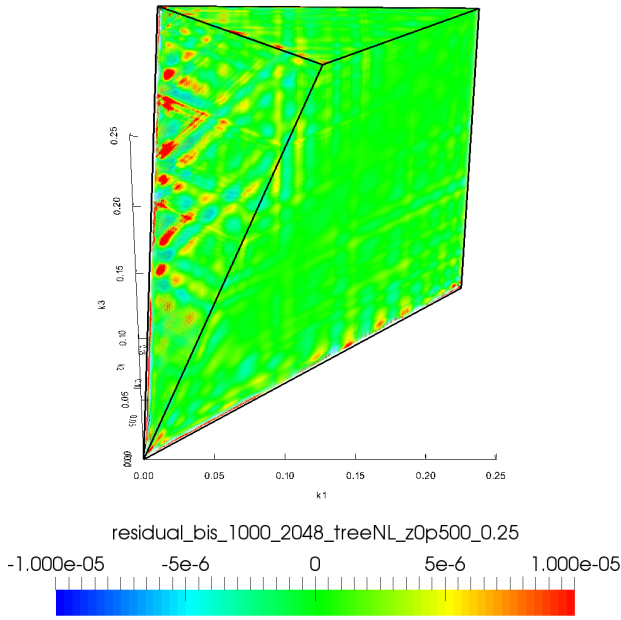
- Fractional deviation of 10^{-6} (with 1000 modes)



Signal



Reconstruction



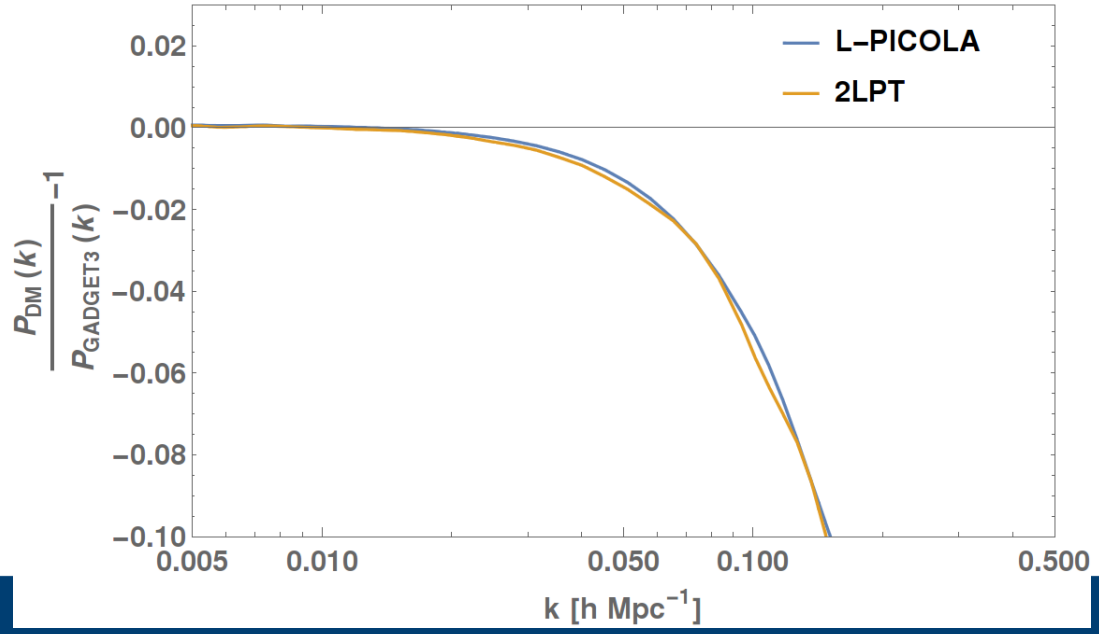
Residuals

Cosmological simulations

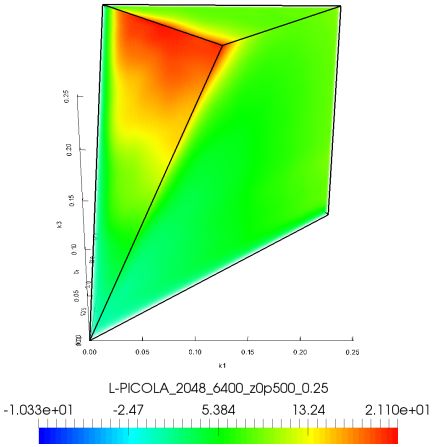
- N-body codes such as GADGET are expensive to run
- Need many runs to reduce statistical errors in estimation of covariance matrices, comparison to theory etc.
- Fast DM codes such as L-PICOLA: more than 100x reduction in CPU-hours (1000x for 2LPT)
- Can benchmark these codes with power spectrum and bispectrum
- Diagnostics:
  - Shape: $\mathcal{S}(B_i, B_j) \equiv \dfrac{\left[B_i, B_j\right]}{\sqrt{\left[B_i, B_i\right]\left[B_j, B_j\right]}}$ Amplitude: $\mathcal{A}(B_i, B_j) \equiv \dfrac{\left[B_i, B_j\right]}{\left[B_i, B_i\right]}$

Results

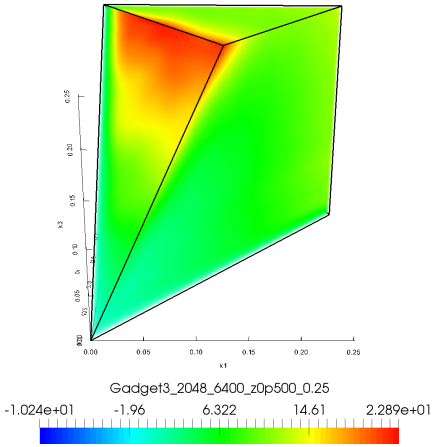
- We ran a 6400 Mpc/h GADGET3 simulation with 2048^3 particles and PMGRID of 2048 for maximum resolution
- We benchmarked L-PICOLA and 2LPT against GADGET3
- We compare their power spectrum and bispectrum



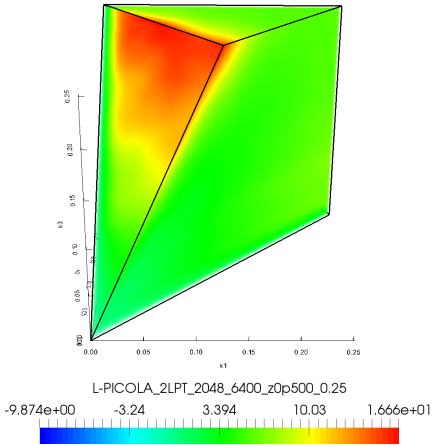
Bispectrum Results



L-PICOLA

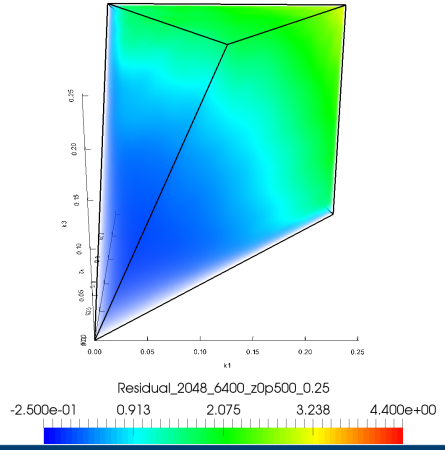


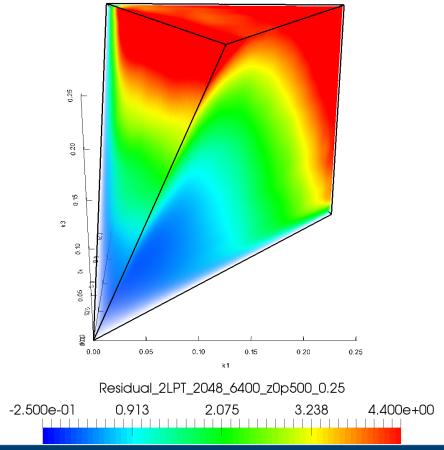
GADGET3



2LPT

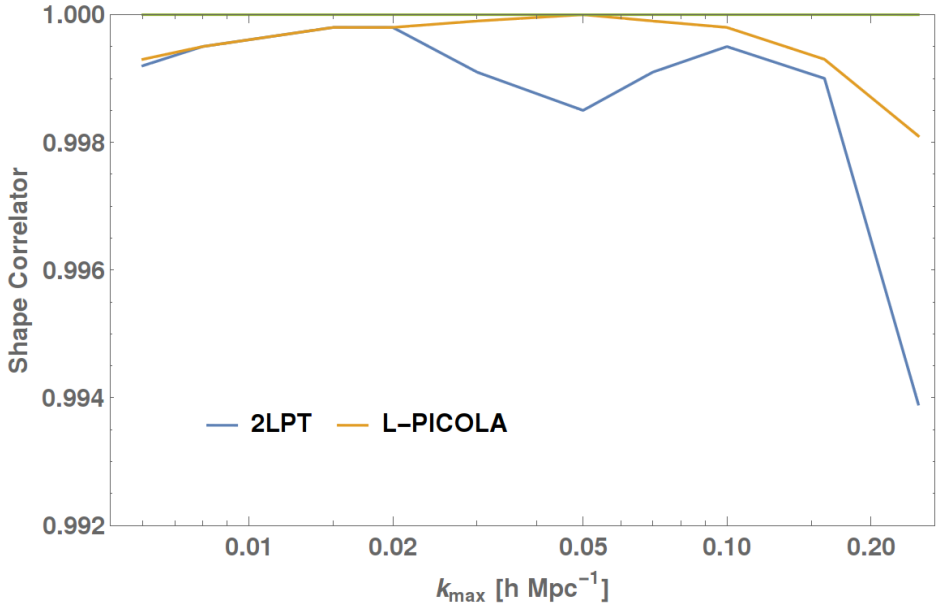
L-PICOLA residuals

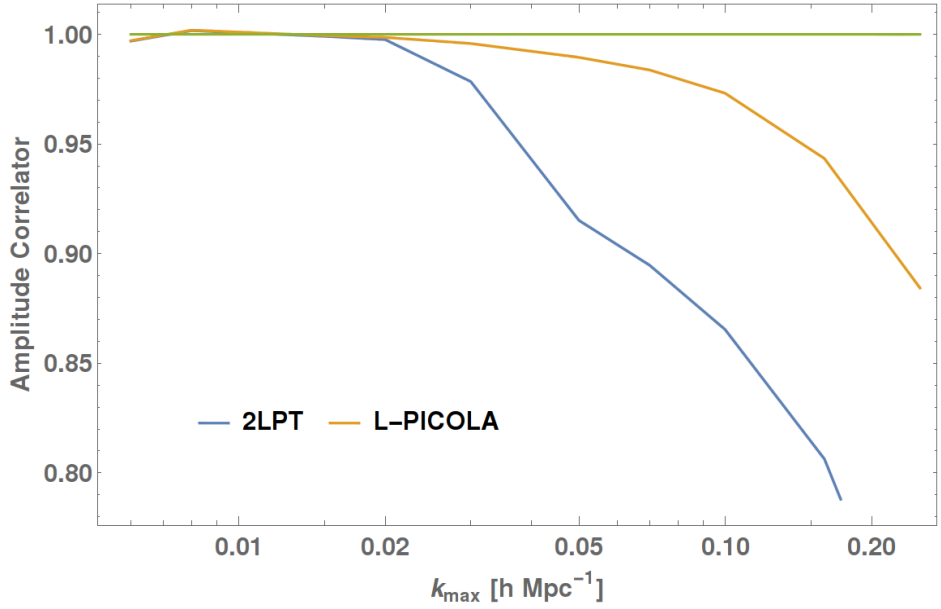




2LPT residuals, 2x magnitude of L-PICOLA ones

Bispectrum Results





Conclusions

Conclusions and Future work

- LSS will become very important cosmological observable
  - Bispectrum computationally difficult but will provide a wealth of information for breaking parameter degeneracies, constrain early universe scenarios, and investigating primordial NG or alternatives to GR
  - Computation made efficient by MODAL-LSS code
- Need many N-body simulations for parameter estimation etc.
  - Fast codes can be benchmarked through bispectrum, and power spectrum can’t
- Will move towards halo codes with galaxy survey data in mind