Reconstruction of BAO Peaks in 1+1 Dimensions

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In this paper we introduce a new way to reconstruct BAO peaks in real space.
title 1: Reconstruction with the Lagrangian Displacement in 1+1 Dimensions
title 2: Baryon Acoustic Oscillations Reconstruction in 1+1 Dimensions.
title 3: BAO Reconstruction in 1+1 Dimensions.

PACS numbers:

I. INTRODUCTION

BAO is a standard ruler in the Universe. Measurement of BAO scale at low redshift provides a test of dark energy. However, nonlinear evolution smears the BAO peaks. In this paper, we reconstruct BAO peaks in real space.

In Section II, we formulate the basic formalism. In Section III, we study study the new method in 1D N-body simulations. In Section IV, we study the distribution function and cross correlations. In Section V, we calculate the covariance matrix and information content.

II. FORMALISM

A. Standard BAO reconstruction

B. Reconstruction algorithm

(1) Solve the displacement $\Psi(q)$ field by ordering of the mass elements.

(2) Take the differential derivative of $\Psi(q)$ to get the reconstructed density field $\delta_r(x) = -\partial\Psi(q)/\partial q$.

or the density field should be given as

$$\delta_r(x) = \frac{1}{1+\partial\Psi(q)/\partial q} - 1, \tag{1}$$

where to linear order $\delta_r(x)$ is given by $-\partial\Psi(q)/\partial q$?

C. Lagrangian displacement

III. SIMULATION

We adopt the 1D N-body simualtions in Ref. [1] and use outputs at $z = 0$. The simulation box is 10^8 Mpc with 3×10^8 grids and 3×10^8 PM elements. We scale the intial density field by the linear growth factor to get the linear density field δ_L at $z = 0$.

In Fig. 1, we plot the power spectra of the linear density field δ_L, the nonlinear density field δ from the simulation, and the density field from Zeldovich approximation $\delta_{\rm ZA}$.

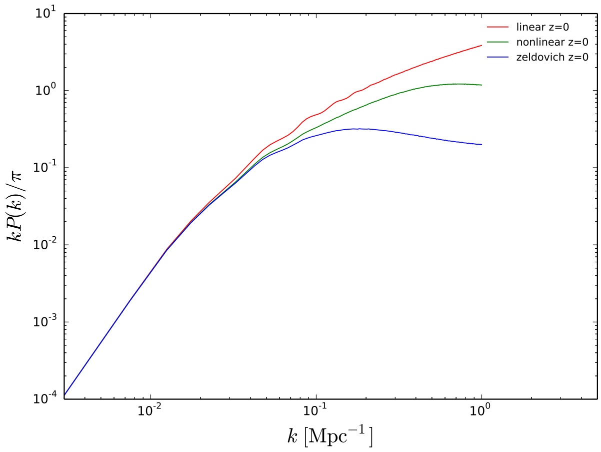

FIG. 1: The power spectra of the linear density field δ_L, the nonlinear density field $\delta_{\rm NL}$ from the simulation, and the density field from Zeldovich approximation $\delta_{\rm ZA}$.

IV. GAUSSIANITY AND CROSS CORRELATION

The initial linear Gaussian density perturbations $\delta_L(\boldsymbol{x})$ evolve due to gravitational interaction. Given any initial linear density field, we have the evolved nonlinear density field $\delta(\boldsymbol{x})$ as a functional of $\delta_L(\boldsymbol{x})$,

$$\delta(\boldsymbol{x}) = F[\delta_L(\boldsymbol{x})], \tag{2}$$

where the gravtitational interaction process determines how the linear density field δ_L is related to the nonlinear density field $\delta_{\rm NL}$.

We can easily decompose the nonlinear density field into two parts,

$$\delta(\boldsymbol{k}) = b(\boldsymbol{k})\delta_L(\boldsymbol{k}) + n(\boldsymbol{k}), \tag{3}$$

where $b(\boldsymbol{k})\delta_L(\boldsymbol{k})$ is correlated with the initial linear density field and $n(\boldsymbol{k})$ is generated in the nonlinear evolution. Here, $b(\boldsymbol{k})$ is often called the "propagator" and $n(\boldsymbol{k})$ is usually called the mode-coupling term [2–4]. The mode-coupling term which arises from the nonlinear evolution contributes as noises when we try to extract the information encoded in the linear density field, like the positions of BAO peaks.

The propagator $b(k)$ and the noise term $n(k)$ can be evaluated easily from the correlations of the nonlinear field δ and the linear field δ_L,

$$\langle\delta\delta_L\rangle = b\langle\delta_L\delta_L\rangle, \quad \langle\delta\delta\rangle = b^2\langle\delta_L\delta_L\rangle + \langle nn\rangle. \tag{4}$$

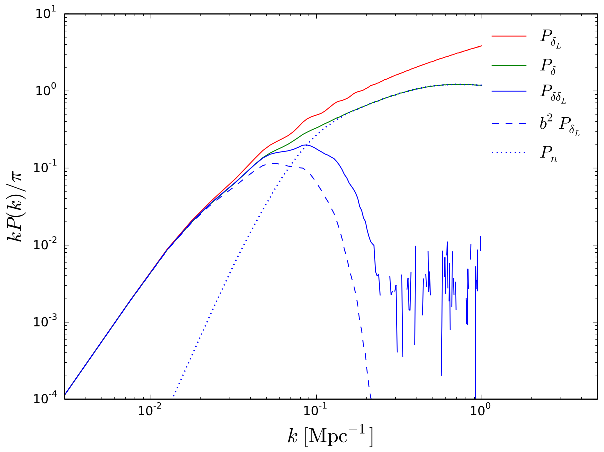

FIG. 2: The power spectra of δ_L and δ. We also plot $b^2 P_L$ and P_n. The noise dominates over the signal when $k \gtrsim 0.06$/Mpc.

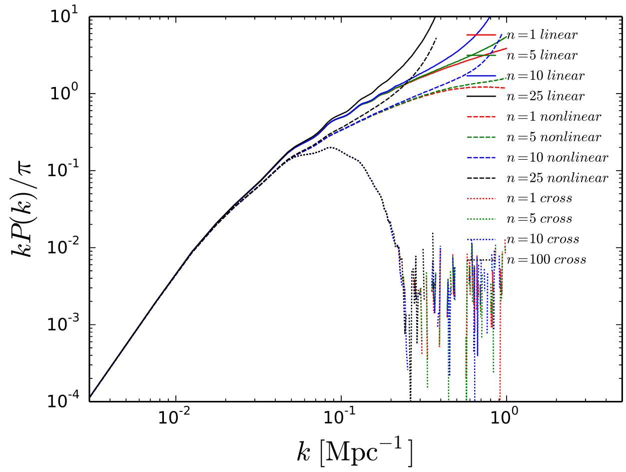

FIG. 3: The power spectra of δ_L and δ with $n = 1/grid$ $n = 5/grid$ and $n = 10/grid$.

Note that δ_L has been rescaled using the linear growth function to the same redshift as δ. The propagator $b(k)$ and the noise power spectrum $P_n(k)$ is given by

$$b(k) = \frac{P_{\delta\delta_L}(k)}{P_{\delta_L}(k)}, \quad P_n(k) = P_\delta(k) - b^2(k) P_{\delta_L}(k). \quad (5)$$

The cross-correltion coefficient of δ and δ_L is

$$r(k) = \frac{P_{\delta\delta_L}(k)}{\sqrt{P_\delta(k) P_{\delta_L}(k)}} = \frac{1}{\sqrt{1+\eta(k)}}, \quad (6)$$

where $\eta = P_n/(b^2 P_{\delta_L})$.

In Fig. 2, we plot the signal $b^2(k)P_L(k)$ and the noise power spectrum $P_n(k)$. The noise dominates over the signal when $k \gtrsim 0.06$/Mpc.

To solve the displacement field, we combine grids to get two fields with five PM elements per grid and ten PM elements per grid, respectively. In Fig. 3, we show the power spectra with different number density. We further get the reconstructed density field δ_r using the algorithm. In Fig. 4, we show the power spectra of δ_r and δ. In Fig. 5, we show the power spectra of δ_r and δ_L.

In Fig. 6, we show the propagator $b(k)$ at $z = 0$ and $z = 10$. In Fig. 8, we show the cross-correlation coefficient at $z = 0$ and $z = 10$.

In Fig. , we show the distributions of the linear and nonlinear density fields.

A. Reconstruction

V. COVARIANCE MATRIX AND INFORMATION CONTENT

The covariance is calculated using 100 simualtions and inormation content ...

Figure 3 covariance matrix for rec. Figure 4, covariance for BAO rec. Figure 5 information mode.

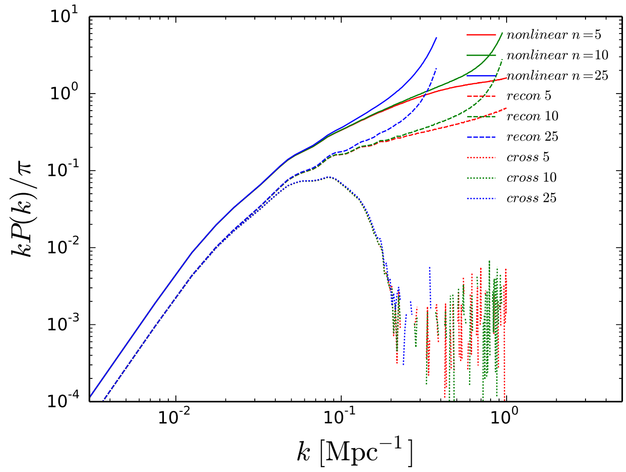

FIG. 4: The power spectra of δ_r and δ with $n = 5/grid$ and $n = 10/grid$.

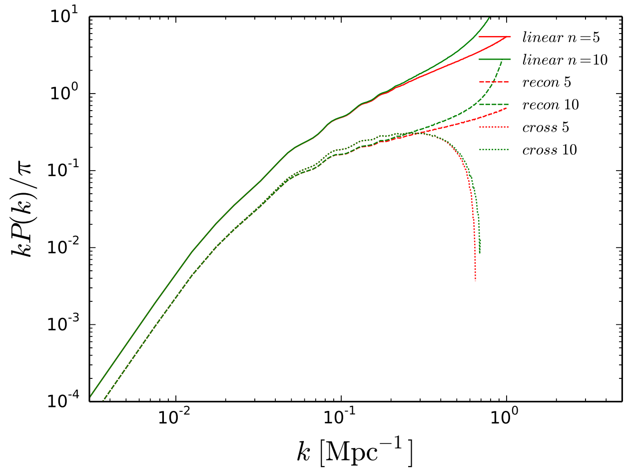

FIG. 5: The power spectra of δ_r and δ_L with $n = 5/grid$ and $n = 10/grid$.

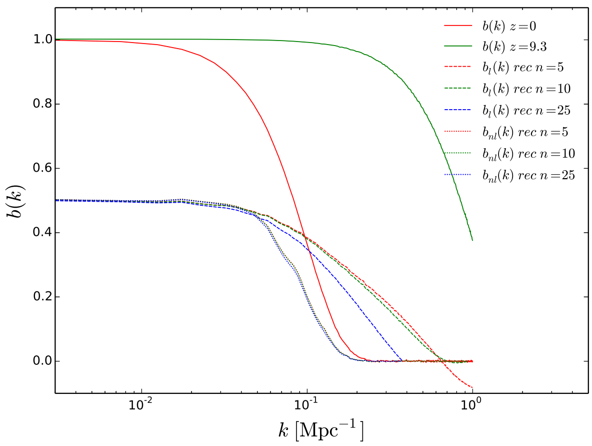

FIG. 6: The propagator $b(k)$ at $z = 0$ and $z = 10$.

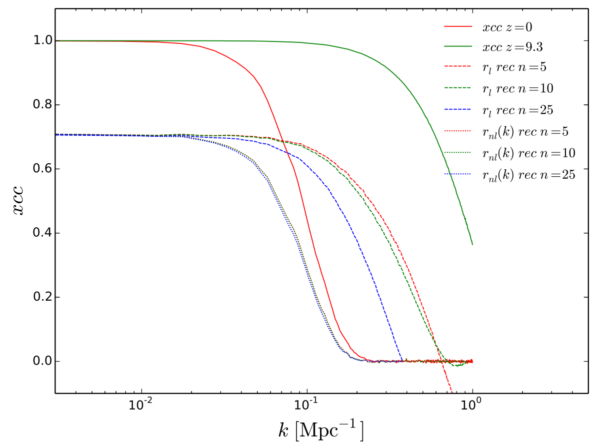

FIG. 7: The cross-correlation coefficient of δ and δ_L at $z = 0$ and $z = 10$.

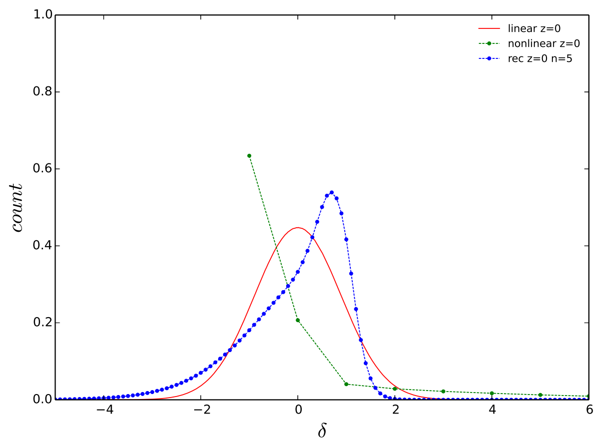

FIG. 8: The distributions of the density fluctuations.

VI. DISCUSSION

—This method can be generalized to the 3D case. We leave this to future work.

VII. ACKNOWLEDGEMENT

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