Displacement field paper

In this paper, we discover the ability of using displacement field to reconstruct initial linear perturbations in the early universe.

I. INTRODUCTION

Introduction goes here. Citation example [1]. Cite Hong-Ming's 1D paper.

The rest of this paper is structured as follows. In section II we describe the simulation and reconstruction algorithm. In section III we show the results of the reconstruction. Discussion and conclusion are in IV.

II. METHOD

Method goes there.

A. Simulation

Cosmological parameters, simulation parameters.

Initial conditions, get linear density field δ_L. Run simulation by code `CUBE` and get the nonlinear density field δ at $z = 0$. `CUBE` uses particle-ID (PID) to record the initial location of particles, and the information is tracked until the $z = 0$ and we can get the displacement vector $\boldsymbol{s} \equiv \boldsymbol{x} - \boldsymbol{q}$ for every particle. Then these vectors are interpolated onto the initial Lagrangian coordinates $\boldsymbol{q}$ of particles and we get the displacement field $\boldsymbol{s}(\boldsymbol{q})$.

B. Reconstruction

Get the raw reconstructed density field $\delta_R = -\nabla \cdot \boldsymbol{s}(\boldsymbol{q})$.

III. RESULTS

Wiener filter. Define

$$r \equiv \frac{\langle \delta_L \delta_R \rangle}{\sqrt{\langle \delta_L \delta_L \rangle \langle \delta_R \delta_R \rangle}} \tag{1}$$

and

$$b^2 \equiv \frac{\langle \delta_R \delta_R \rangle}{\langle \delta_L \delta_L \rangle}. \tag{2}$$

We try to decompose δ_L into two components,

$$\delta_L = r' \delta_R + \delta_N, \tag{3}$$

where $r'\delta_R$ is completely correlated with δ_L, and the uncorrelated part δ_N is generated by the nonlinear evolution. To do this, we first correlate equation (3) with δ_R,

$$\langle \delta_L \delta_R \rangle = r' \langle \delta_R \delta_R \rangle + \langle \delta_N \delta_R \rangle, \tag{4}$$

and vanish the second term in the right-hand-side. Then

$$r' = \frac{\langle \delta_L \delta_R \rangle}{\langle \delta_R \delta_R \rangle} = \frac{r}{b}. \tag{5}$$

Then the mode-coupling term

$$\delta_N = \delta_L - \frac{r}{b}\delta_R. \tag{6}$$

We next square equation (3) and gives

$$\langle \delta_L \delta_L \rangle = \frac{r^2}{b^2} \langle \delta_R \delta_R \rangle + \langle \delta_N \delta_N \rangle + 2\frac{r}{b} \langle \delta_R \delta_N \rangle, \tag{7}$$

and the third term of right-hand-side also vanishes. As a result,

$$\langle \delta_N \delta_N \rangle = \frac{1 - r^2}{b^2} \langle \delta_R \delta_R \rangle \tag{8}$$

and a Wiener filter can be constructed as

$$W = \frac{r^2}{r^2 + 1 - r^2} = r^2. \tag{9}$$

From equation (3), multiplying W, we obtain the optimal reconstructed linear density field by

$$\tilde{\delta}_L = W\frac{r}{b}\delta_R = \frac{r^3}{b}\delta_R. \tag{10}$$

From equation (7), multiplying W^2, the reconstructed linear power spectrum is giving by

$$\begin{aligned} \tilde{P} &= W^2 \langle \delta_L \delta_L \rangle \\ &= r^2 \frac{r^2}{b^2} \langle \delta_R \delta_R \rangle + r^2 \langle \delta_N \delta_N \rangle \\ &= \frac{r^2}{b^2} \langle \delta_R \delta_R \rangle. \end{aligned} \tag{11}$$

IV. DISCUSSION AND CONCLUSION

Discussion goes here.

ACKNOWLEDGEMENTS

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[1] J. Harnois-Déraps *et al.*, Mon. Not. R. Astron. Soc.**436**, 540 (2013), 1208.5098.