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Current Status

- Lagrangian Reconstruction Algorithm (Eisenstein, Seo et al. 2007)
- Eulerian Reconstruction Algorithm (Schmittfull et al. 2015)
- Non-linear Reconstruction Method (Zhu et al. 2017)
- …

Zhu et al. ArXiv Eprint 1611.09638 2017
Dynamical Reconstruction: Theory

- **Theory**

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<td><strong>Governing Equation</strong></td>
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## Dynamical Reconstruction: Theory

- **Theory**

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Dynamical reconstruction in action

\[ \nabla^2 \phi = 4\pi G \rho \]

\[ \frac{dr}{dt} = +u, \quad \frac{du}{dt} = -\nabla \phi \]

plot credited to EAGLE simulation
Dynamical reconstruction in action

\[ \nabla^2 \phi = 4\pi G \rho \]

\[ \frac{d\mathbf{r}}{dt} = +\mathbf{u}, \quad \frac{d\mathbf{u}}{dt} = -\nabla \phi \]

\[ \nabla^2 \phi = 4\pi G \rho \]

\[ \frac{d\mathbf{r}}{dt} = -\mathbf{u}, \quad \frac{d\mathbf{u}}{dt} = +\nabla \phi \]

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**Dynamical Reconstruction: Theory**

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- **what is this good for ?**
  - Accessing more linear modes by moving the observation to earlier times
  - BAO reconstruction
Dynamical Reconstruction: Challenges

- incomplete phase space information
- Velocity reconstruction at late time

\[ \mathbf{x}(t) = \mathbf{q} + \Psi(\mathbf{q}, t) \tag{Lagrangian Point of view} \]

\[ \nabla \cdot \Psi = -\delta \quad \mathbf{v} = aHf\Psi \tag{Zeldovich Approximation} \]

- Decaying modes

\[ \delta(\mathbf{x}, t) = A(\mathbf{x}, t)D_1(t) + B(\mathbf{x}, t)D_2(t) \]

\[ D_1(t) \propto t^{2/3} \propto a, \quad D_2(t) \propto t^{-1} \propto a^{-3/2} \quad (\Omega_m = 1) \]
Dynamical Reconstruction: Method

- Simulation
  - Algorithm: P3M; Parameters: Planck
  - Box size: $512^3$ Mpc/h
  - Number of particles: $128^3$
- Algorithm of dynamical reconstruction
  - Zeldovich reconstruction of velocity at initial redshift
  - Inverse particle mesh code
- Accuracy Checks
  - Matter (velocity) power spectrum
  - Matter (velocity) correlation coefficient

\[
\rho_m = \frac{P_{mm}(k)_{\text{true}} \times \text{recon}}{\sqrt{P_{mm}(k)_{\text{true}} P_{mm}(k)_{\text{recon}}}}
\]

\[
\rho_v = \frac{P_{vv}(k)_{\text{true}} \times \text{recon}}{\sqrt{P_{vv}(k)_{\text{true}} P_{vv}(k)_{\text{recon}}}}
\]
Dynamical Reconstruction:

simple test
Dynamical Reconstruction Step 1: Velocity reconstruction at initial redshift

- velocity reconstruction at $z = 0.4$

- $R$: smoothing scale for density

- Linear theory:
  
  $$ p_{vv}(k) = a^2 H^2 f^2 P_{mm}(k)/k^2 $$
  
  $$ p_{\delta \theta}(k) = aH f P_{mm}(k)/k^2 \quad (\theta = \nabla \cdot \mathbf{v}) $$
Dynamical Reconstruction step 2: Moving from $z=0.4$ to 0.6 (Move back 1.43 Gyr)

Matter Power-spectrum

Velocity Power-spectrum

Matter Correlation coefficient

Velocity Correlation coefficient

$\rho_m = \frac{P_{mm}(k)_{true \times recon}}{\sqrt{P_{mm}(k)_{true}P_{mm}(k)_{recon}}} - 1$

$\rho_v = \frac{P_{vv}(k)_{true \times recon}}{\sqrt{P_{vv}(k)_{true}P_{vv}(k)_{recon}}} - 1$

98% reconstruction at $k=0.5 \, h/\text{Mpc}$
Dynamical Reconstruction: how to improve?

- Smoothing scales, mesh size
- number of particles
- leap frog algorithm
- ......
Dynamical Reconstruction: velocity construction comparison

Planck intermediate results. XXXVII 2015
Future direction of dynamic reconstruction project

- theory paper
  - parameters check: smoothing scales, mesh size, number of particles
  - comparison with previous reconstruction paper
    - BAO reconstruction
    - velocity reconstruction
- data paper
  - test with galaxies
  - apply to real data
    - doing cosmology analysis with more linear fields
    - velocity reconstruction
    - BAO reconstruction
  - relative velocity between dark matter and baryons