Extracting Non-Gaussian Information from Large-scale Structure

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Advanced Workshop on Cosmological Structures from Reionization to Galaxies

ICTP, Trieste, Italy
12 May, 2015

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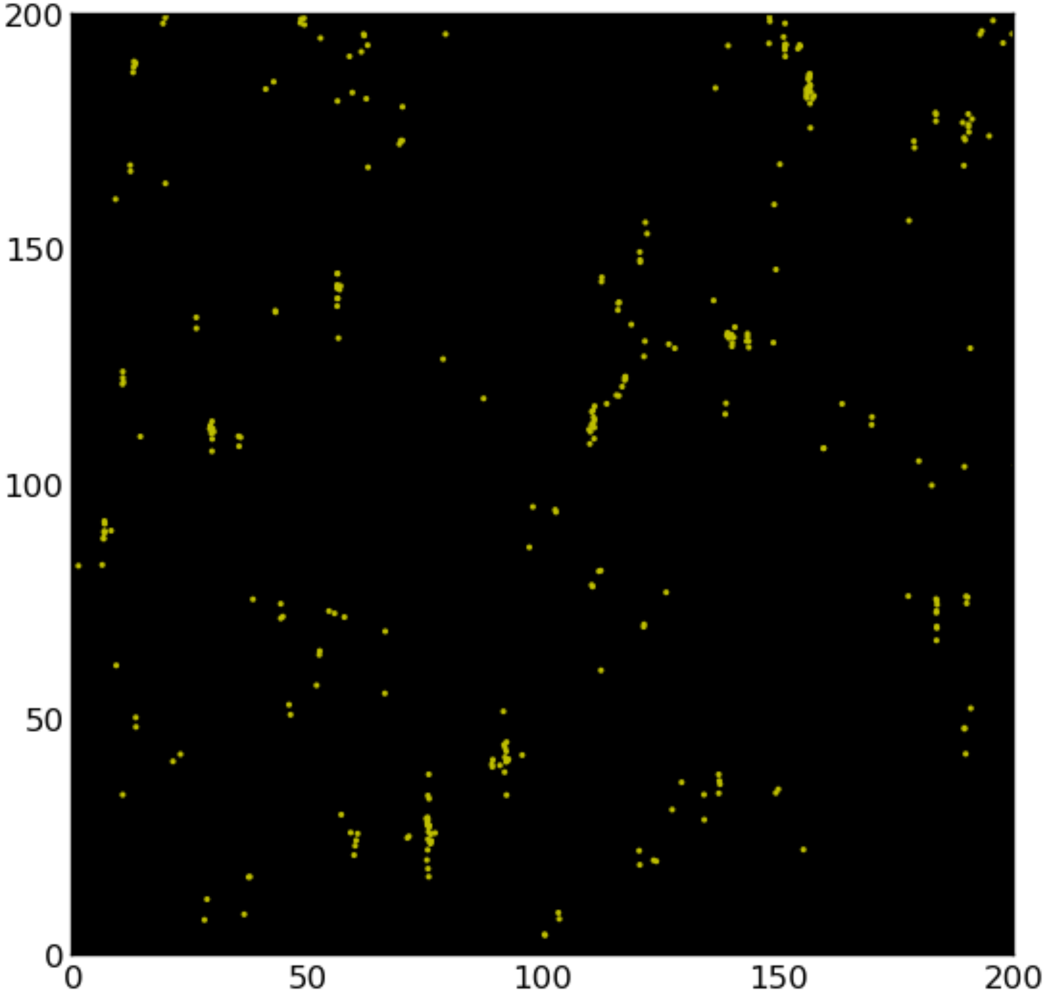
Outline

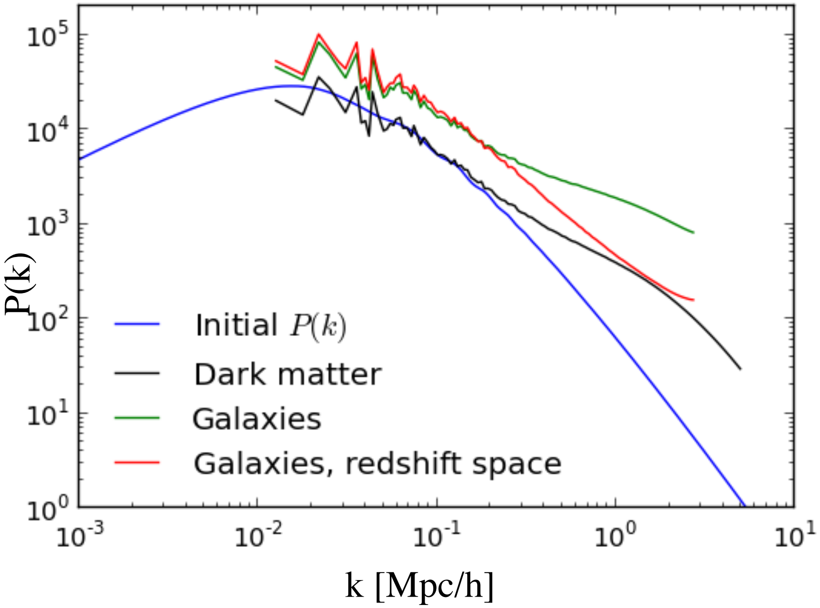
- Large-scale structure as a cosmological probe
- Beyond Gaussian statistics:
  - Log and Gaussianization transform
  - Higher-point statistics
- Summary and future work

Large-Scale Structure

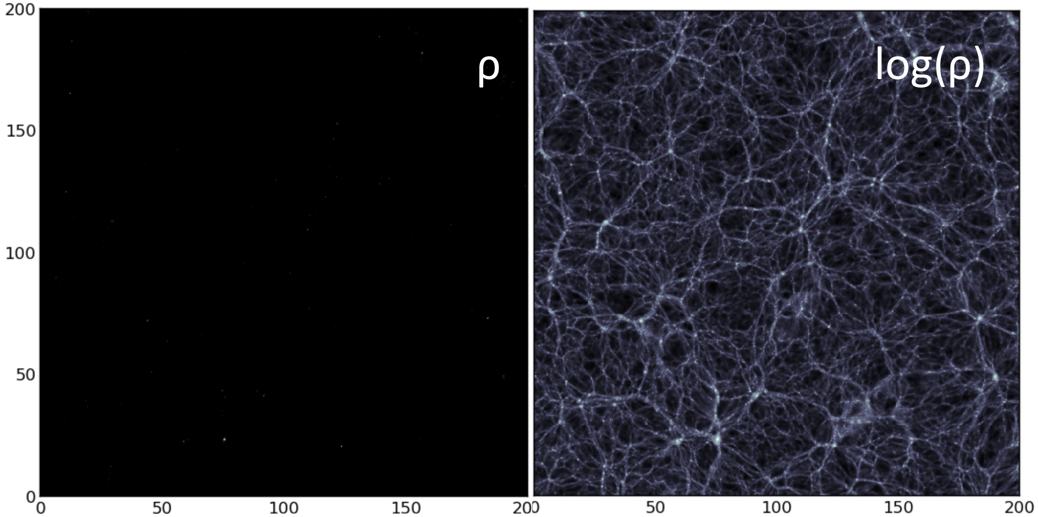


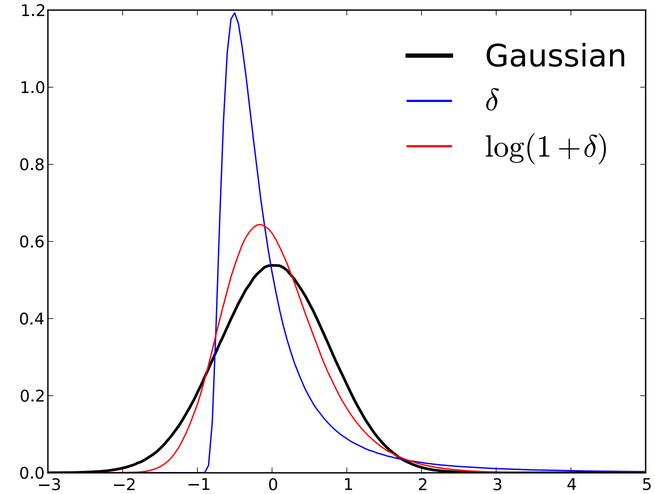
Systematics:

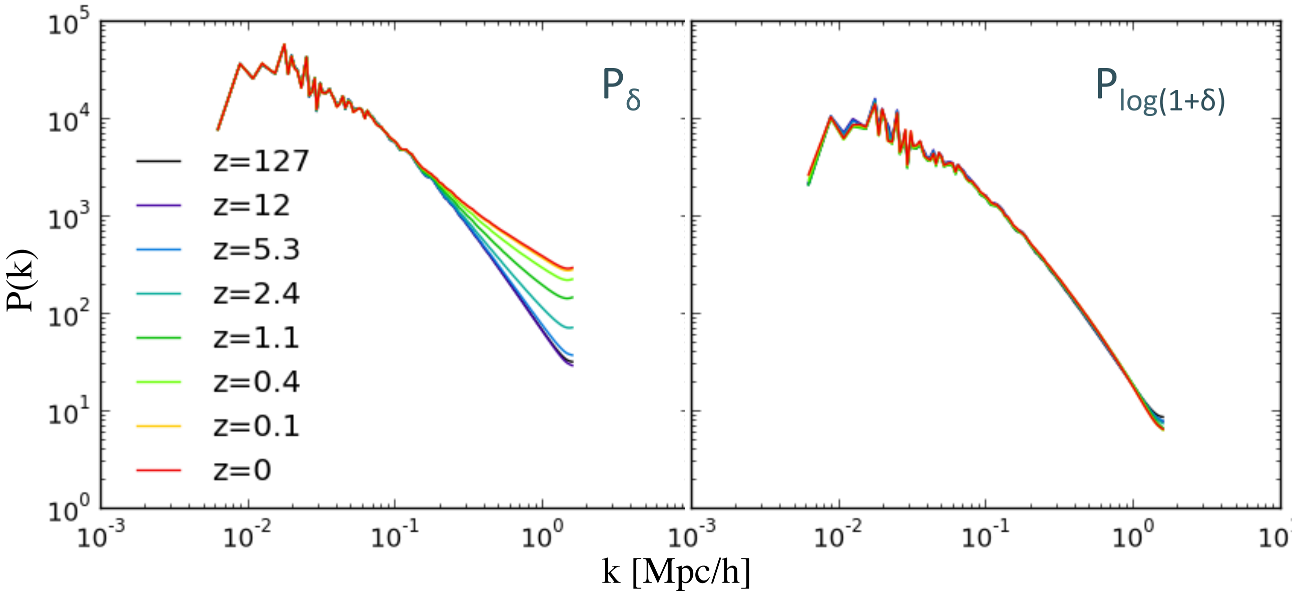
- Time evolution of matter distribution (nonlinearity)
- Galaxy bias
- Redshift-space distortions



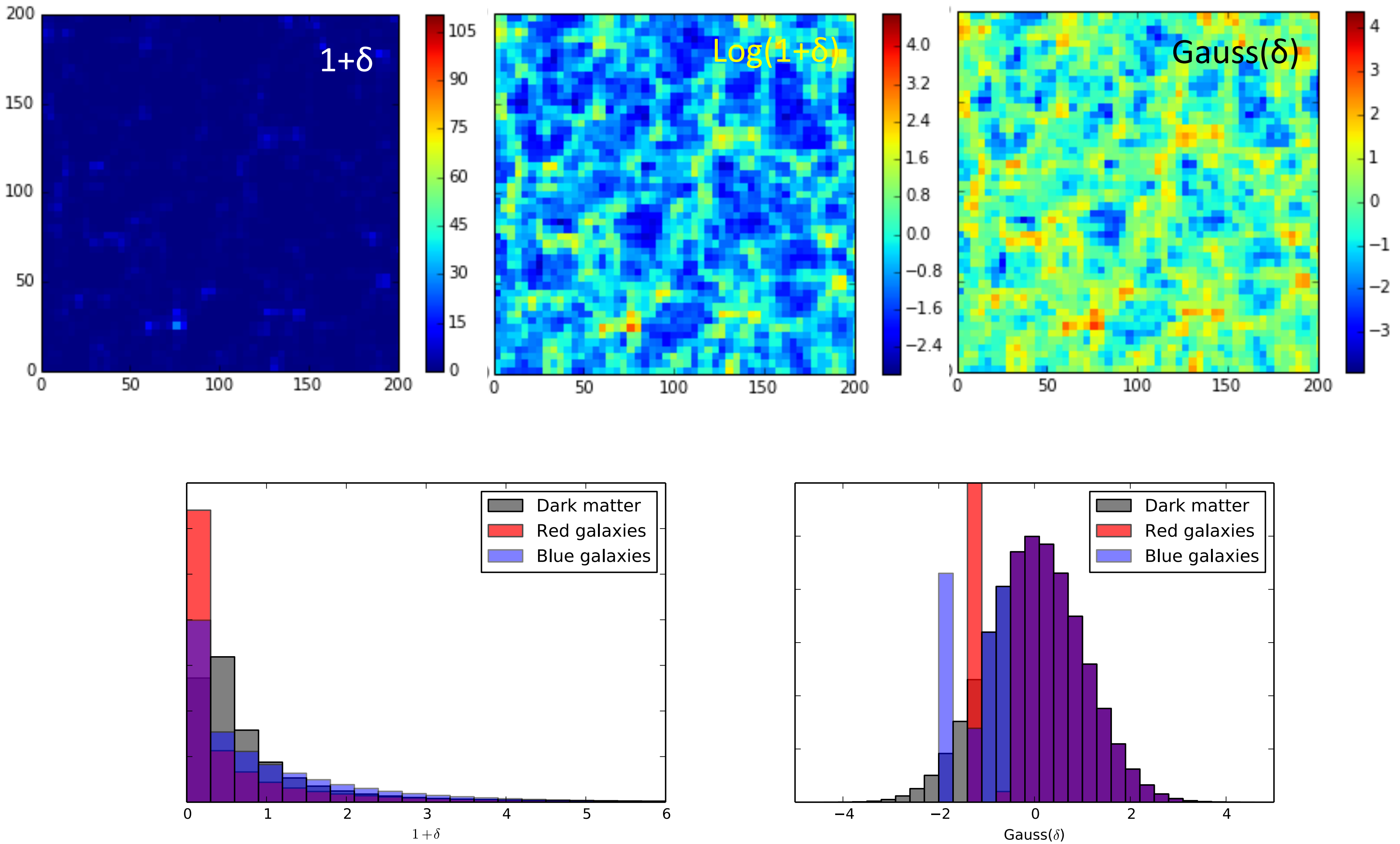
Log transform







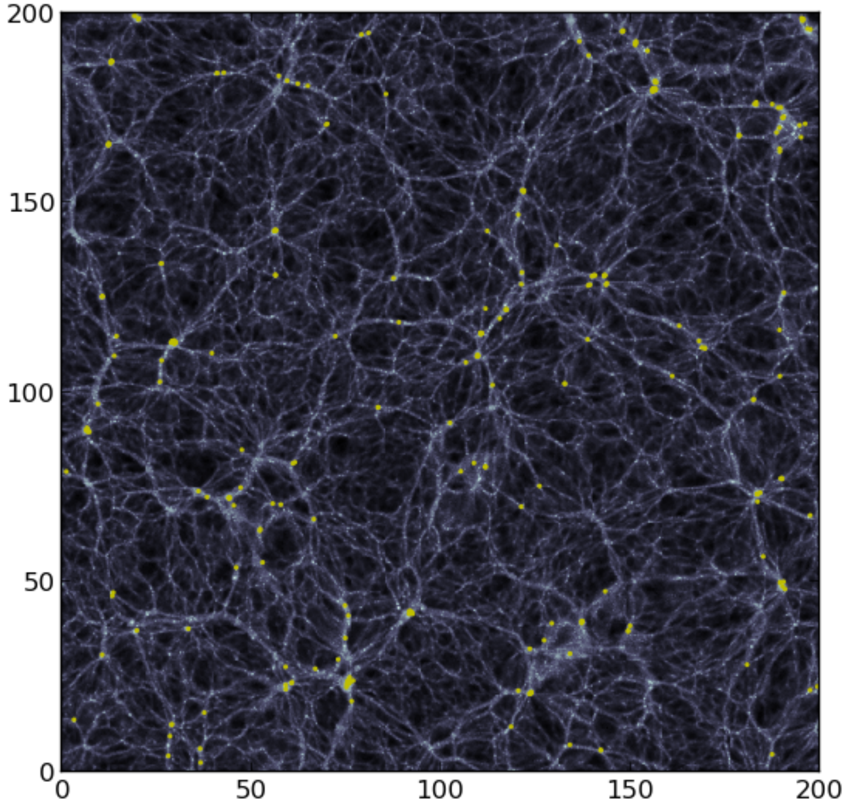
Gaussianization transform



Decoupling Clustering and Tracer Bias

If $\delta_g = f(\delta_{DM})$

then $\mathrm{Gauss}(\delta_g) = \mathrm{Gauss}(\delta_{DM})$



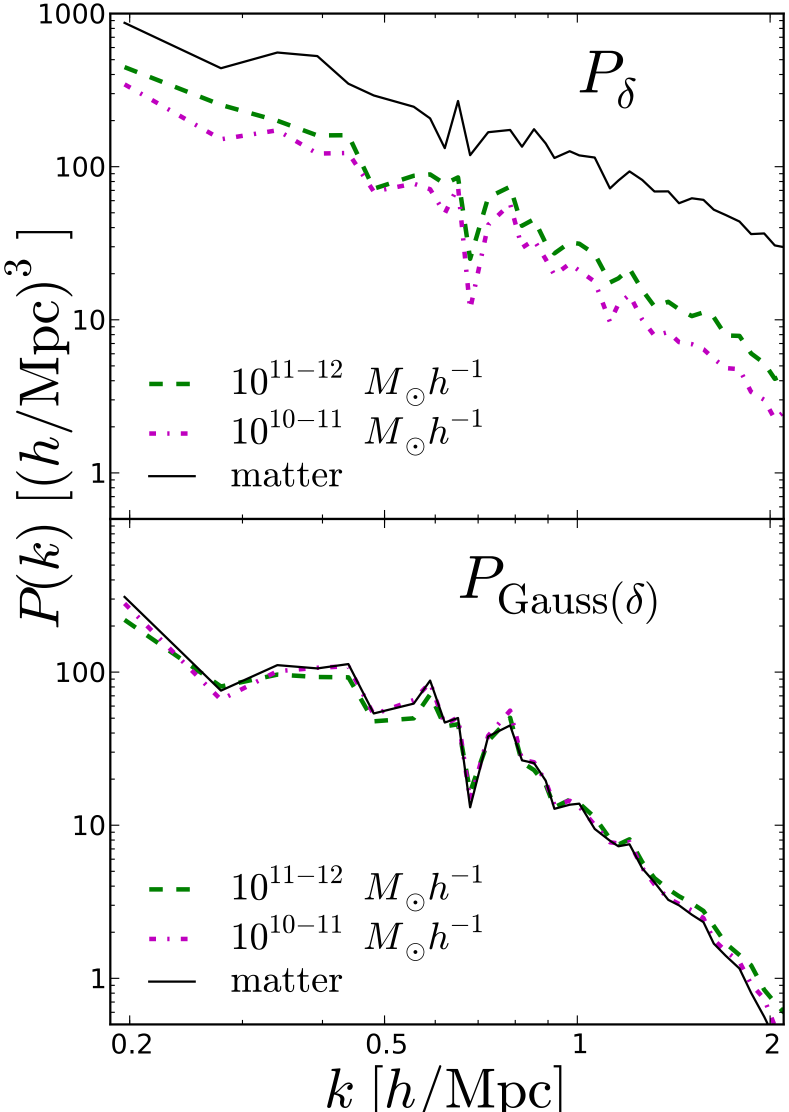
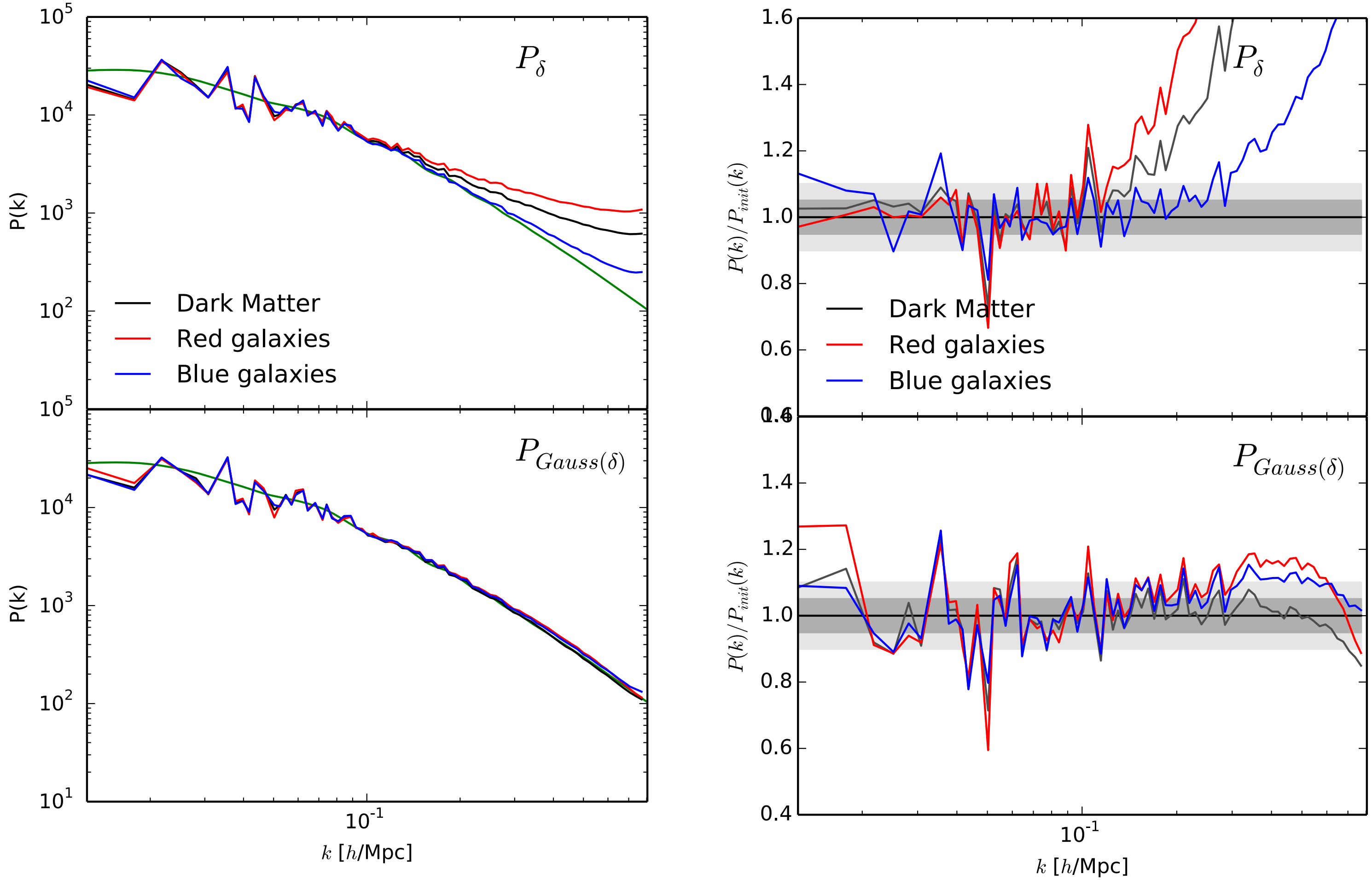


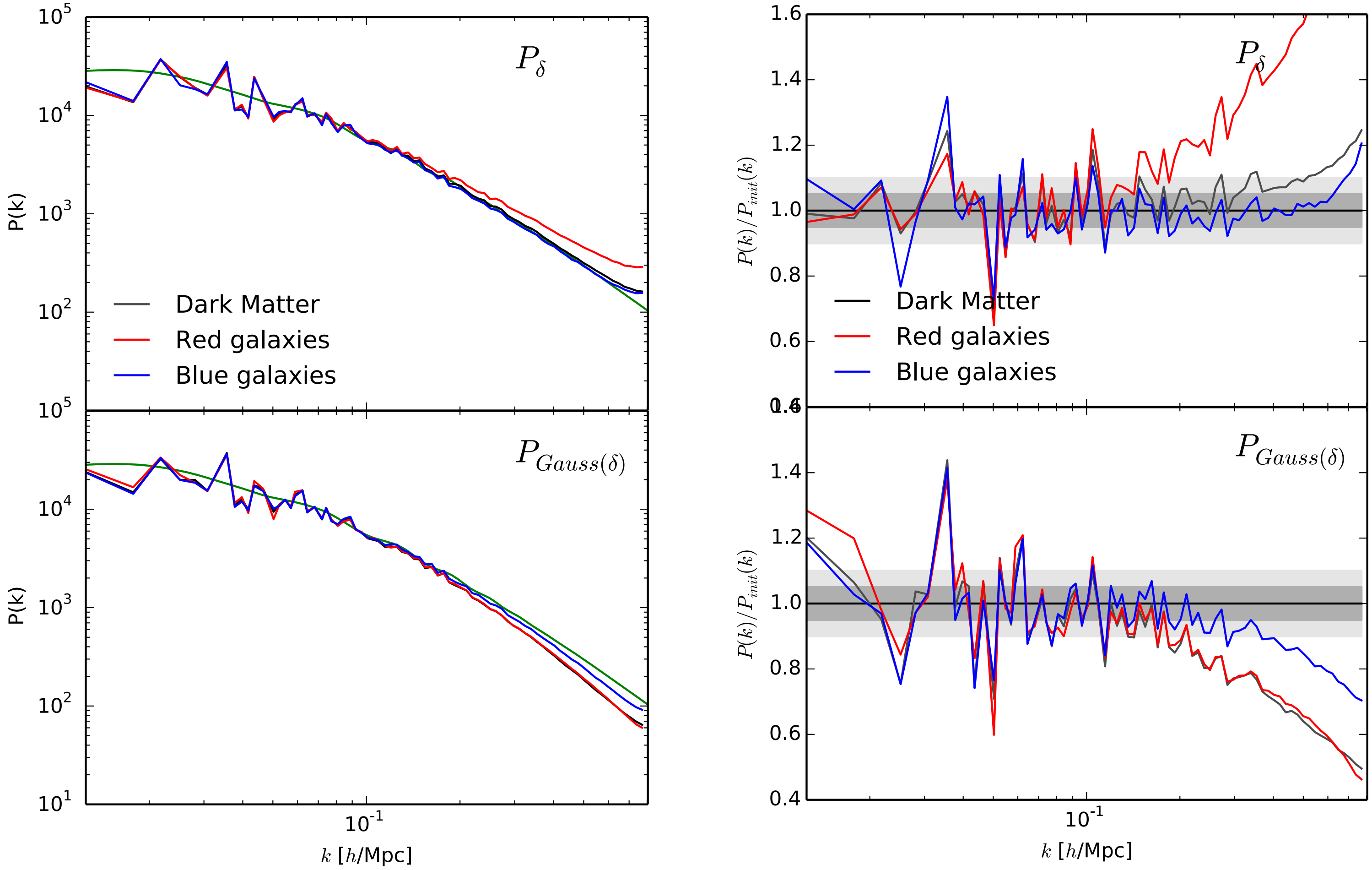
Figure: Mark Neyrinck

Decoupling Clustering and Tracer Bias



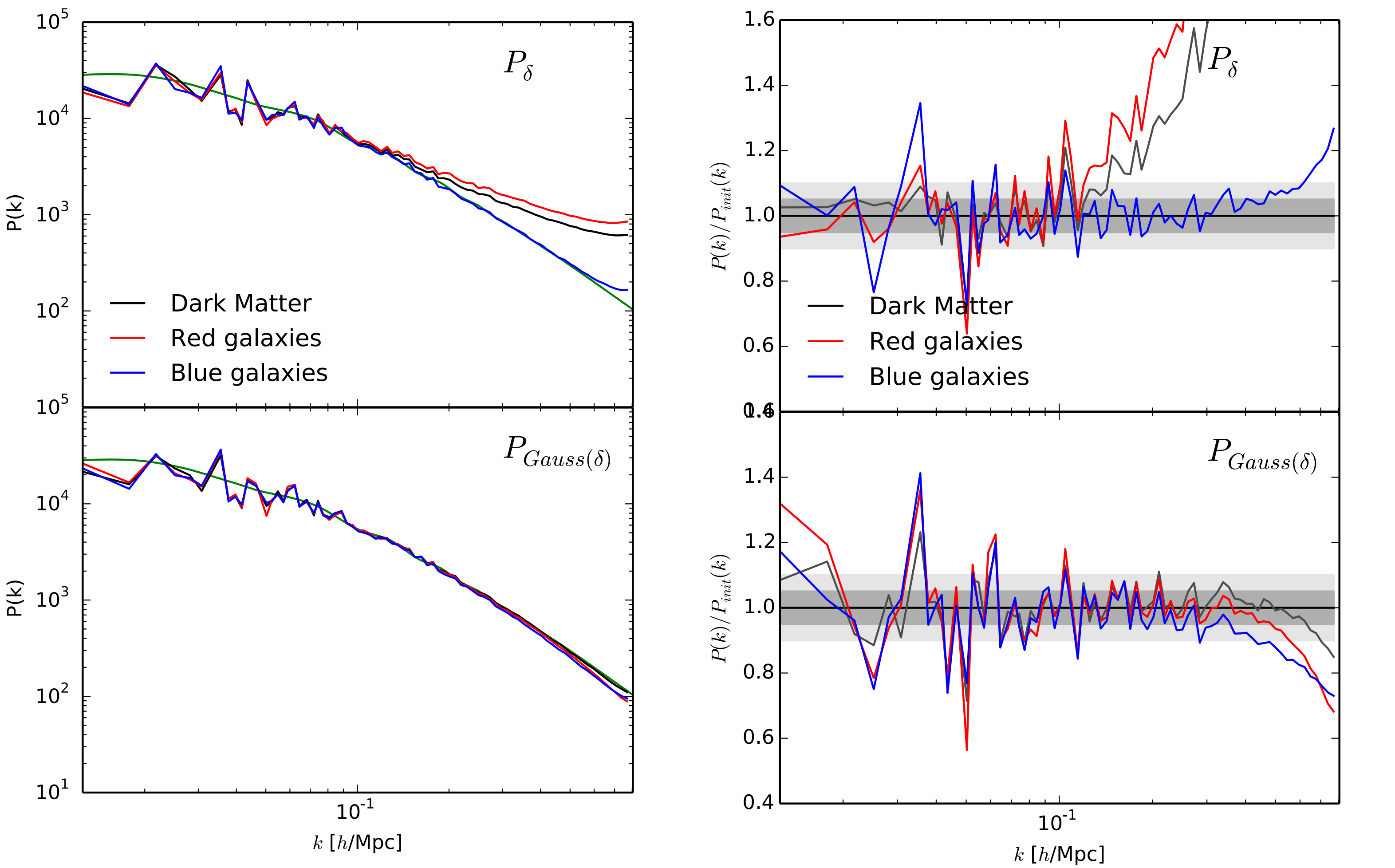
Real space

Decoupling Clustering and Tracer Bias



Redshift space

Decoupling Clustering and Tracer Bias

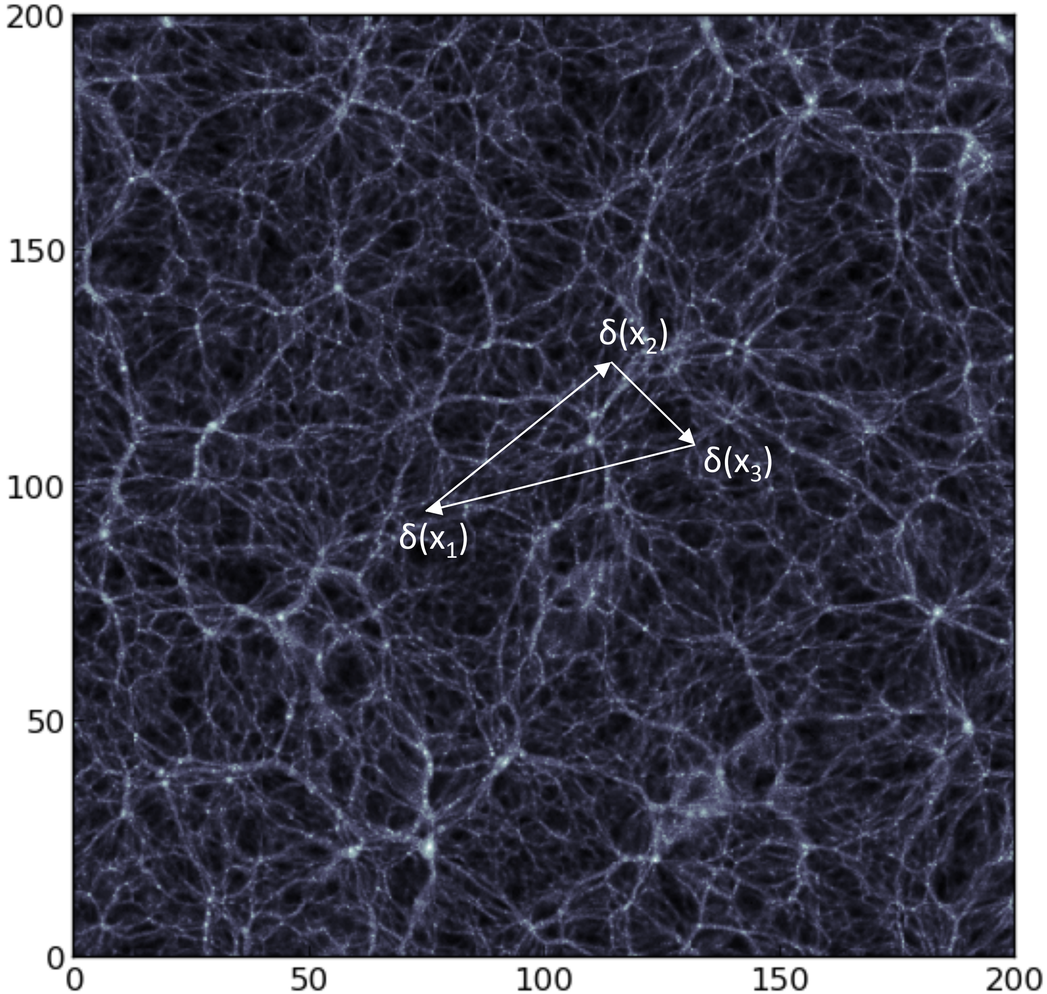


collapsed FoG

Higher-point statistics

$$\zeta(r_1, r_2, r_3) = \langle \delta(\mathbf{x}_1)\delta(\mathbf{x}_2)\delta(\mathbf{x}_3) \rangle$$

$$\langle \delta(\boldsymbol{k}_1)\delta(\boldsymbol{k}_2)\delta(\boldsymbol{k}_3) \rangle \equiv (2\pi)^3 B(k_1, k_2, k_3)\delta_D(\boldsymbol{k}_1 + \boldsymbol{k}_2 + \boldsymbol{k}_3)$$



Galaxy 3-point correlation function/bispectrum contains information about:

- Galaxy bias
- Primordial non-Gaussianity/ inflation
- Growth of structure/gravity

3-point Correlation Function

Lagrangian Perturbation Theory:

$$\boldsymbol{x}(\tau) = \boldsymbol{q} + \boldsymbol{\Psi}(\boldsymbol{q}, \tau).$$

$$\boldsymbol{\Psi}(\boldsymbol{q}, \tau) = \boldsymbol{\Psi}^{(1)}(\boldsymbol{q}, \tau) + \boldsymbol{\Psi}^{(2)}(\boldsymbol{q}, \tau) + \cdots .$$

Real space result:

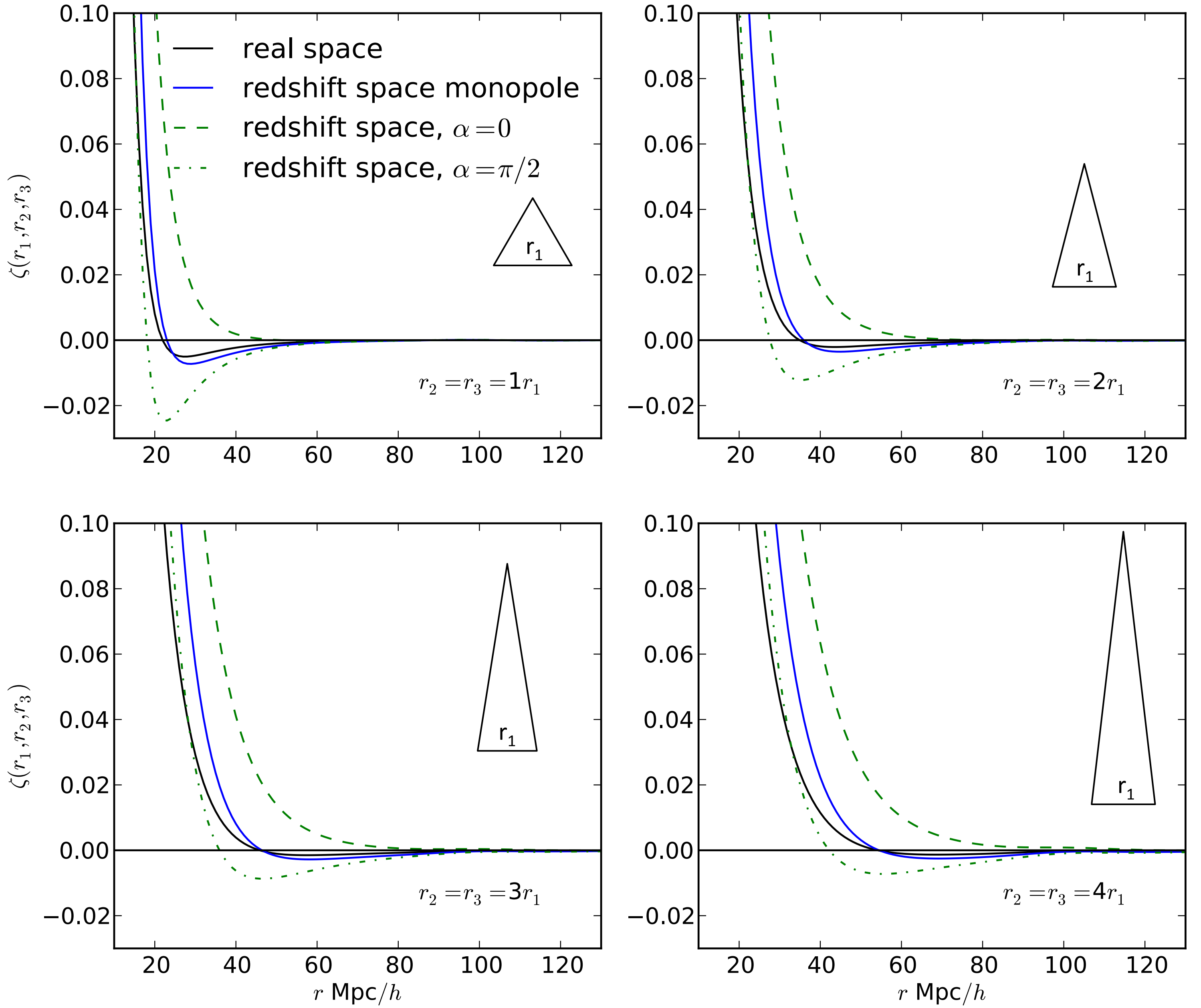
$$\zeta(r_1, r_2, r_3) = D^4 \left(\frac{34}{21} \xi_0^0(r_1) \xi_0^0(r_3) - \cos\theta_{31} \left(\xi_1^1(r_1) \xi_1^{-1}(r_3) + \xi_1^{-1}(r_1) \xi_1^1(r_3) \right) + \frac{2}{21} \left(1 + 3\cos 2\theta_{31}\right) \xi_2^0(r_1) \xi_2^0(r_3) + 2 \text{ cyclic} \right) .$$

RSD and (nonlocal) bias:

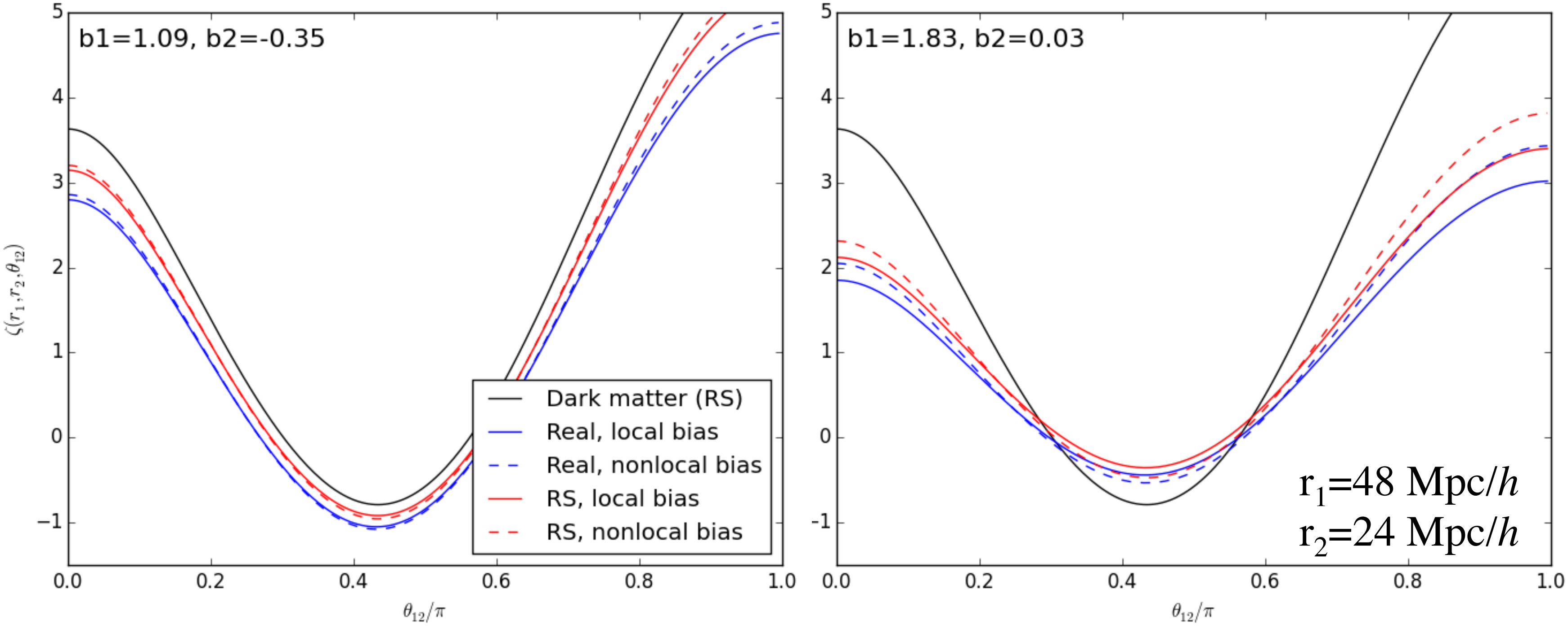
$$\mathbf{s} = \mathbf{x}(\mathbf{q}) + f(\Psi(\mathbf{q}) \cdot \hat{n})\hat{n}$$

$$\delta_{x,g}(\mathbf{x}, t) = b_1 \delta(\mathbf{x}, t) + \frac{b_2}{2}(\delta^2(\mathbf{x}, t) - \sigma^2) + \frac{b_{s^2}}{2}(s^2(\mathbf{x}, t) - \langle s^2 \rangle)$$

Results: Dark Matter



Results: Biased tracers



Summary & Future Work

- Usual 2-point statistics of the matter density field do not capture the full cosmological information
- Log/gaussianization transform accesses non-Gaussian information in galaxy density fields:
  - Decouples clustering information and tracer bias
  - May not be as effective in redshift space
- Higher-point statistics also access non-Gaussian information
  - Bias and RSD must be included in analytic models
  - Will test configuration-space model against N-body simulations
  - Possibilities for extending model beyond tree-level PT, including Fingers of God, etc

Thank you!