Quantifying the non-Gaussianity in the EoR 21-cm signal through Bispectrum

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with

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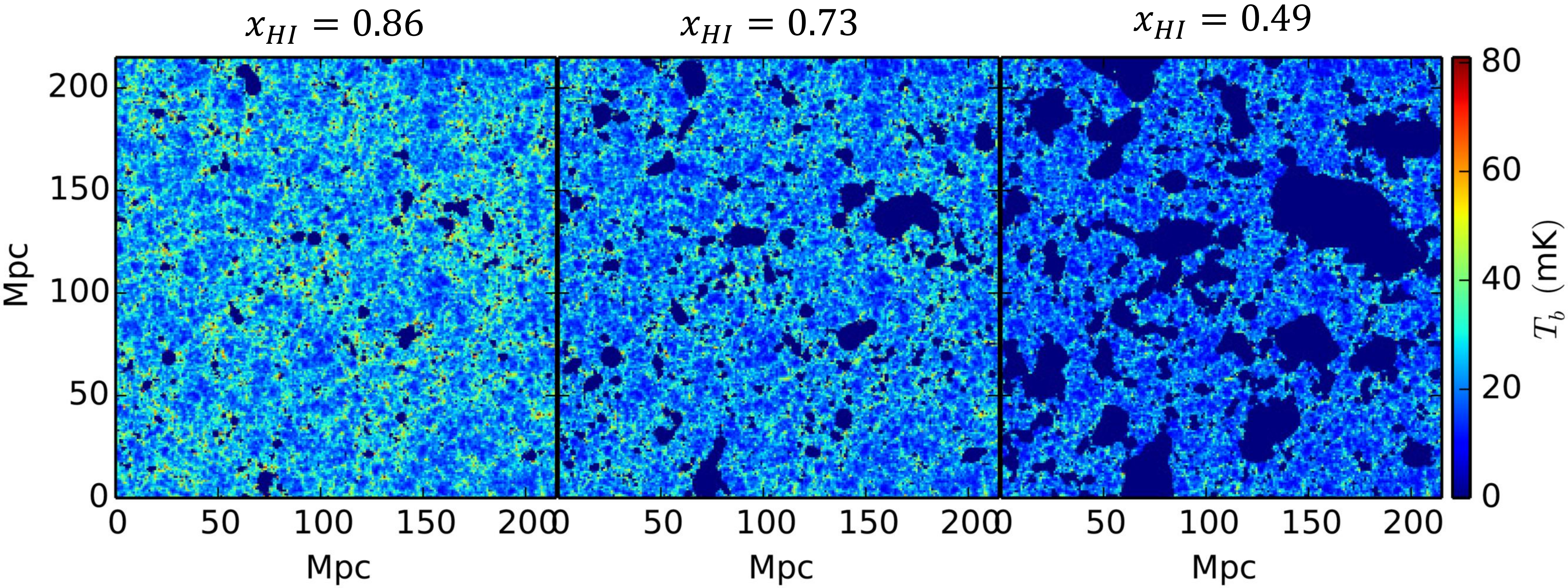
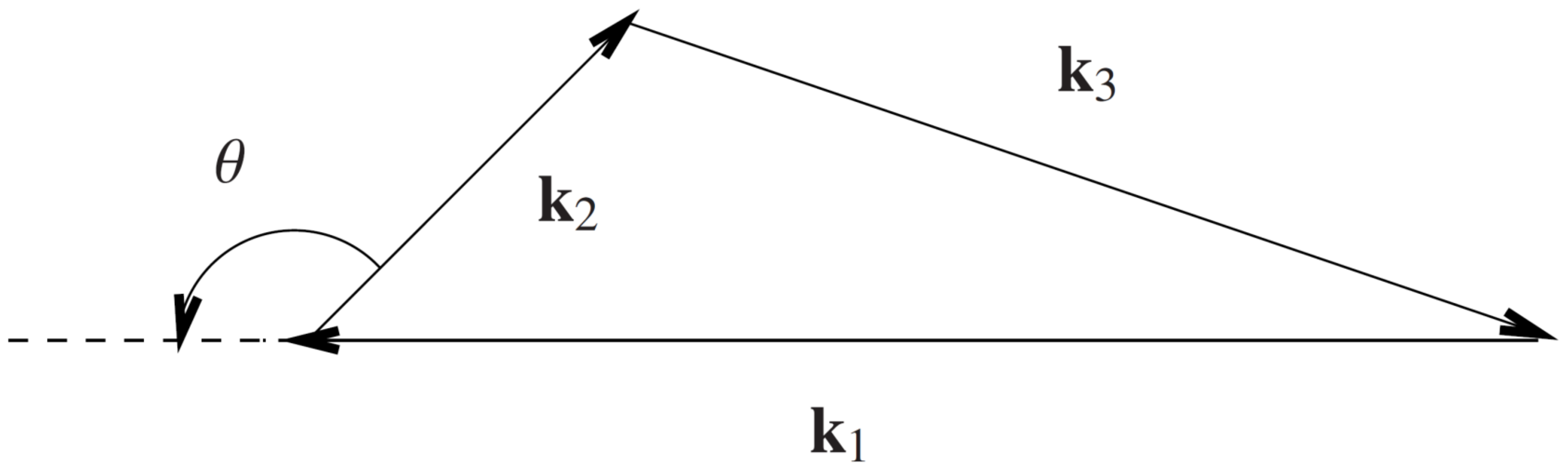
EoR 21-cm signal is highly non-Gaussian



Power spectrum will not quantify the signal completely

Quantifying the non-Gaussianity in the EoR 21-cm signal

Bispectrum: $$\langle \Delta_b(\mathbf{k}_1)\Delta_b(\mathbf{k}_2)\Delta_b(\mathbf{k}_3)\rangle = V\delta^{K}_{\mathbf{k}_1+\mathbf{k}_2+\mathbf{k}_3,0}\, B_b(\mathbf{k}_1,\mathbf{k}_2,\mathbf{k}_3)$$



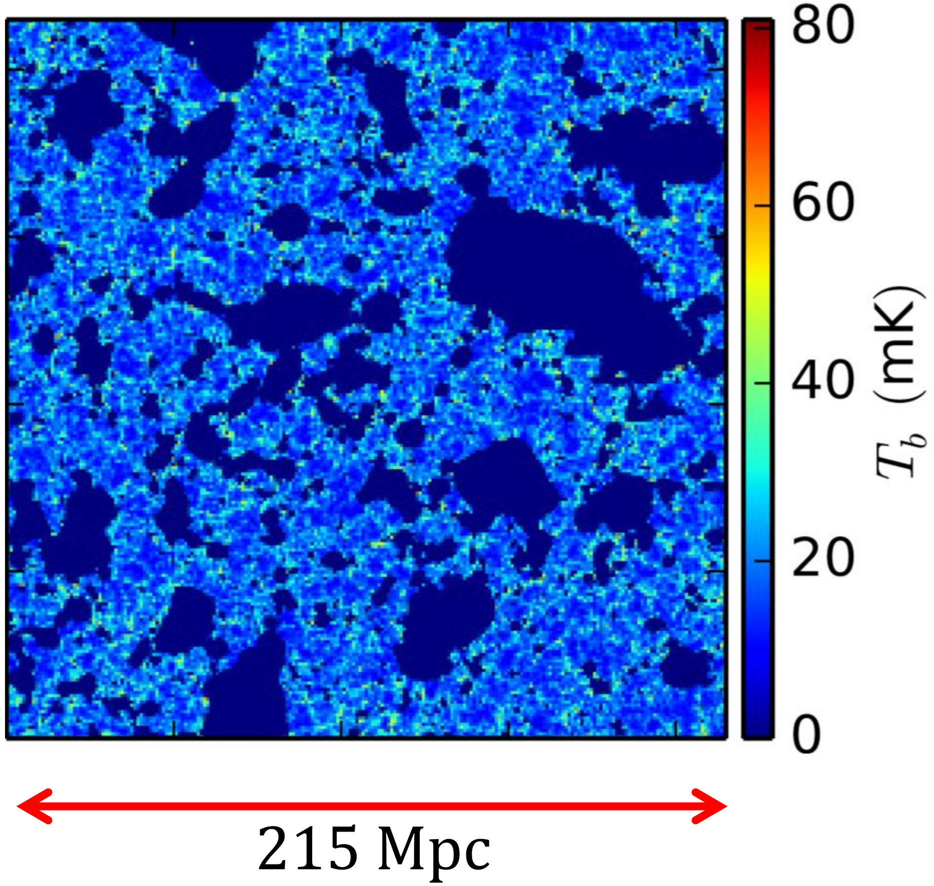
Motivation:

- The redshifted 21-cm signal from EoR is highly non-Gaussian

- Bispectrum can quantify this non-Gaussianity in the signal

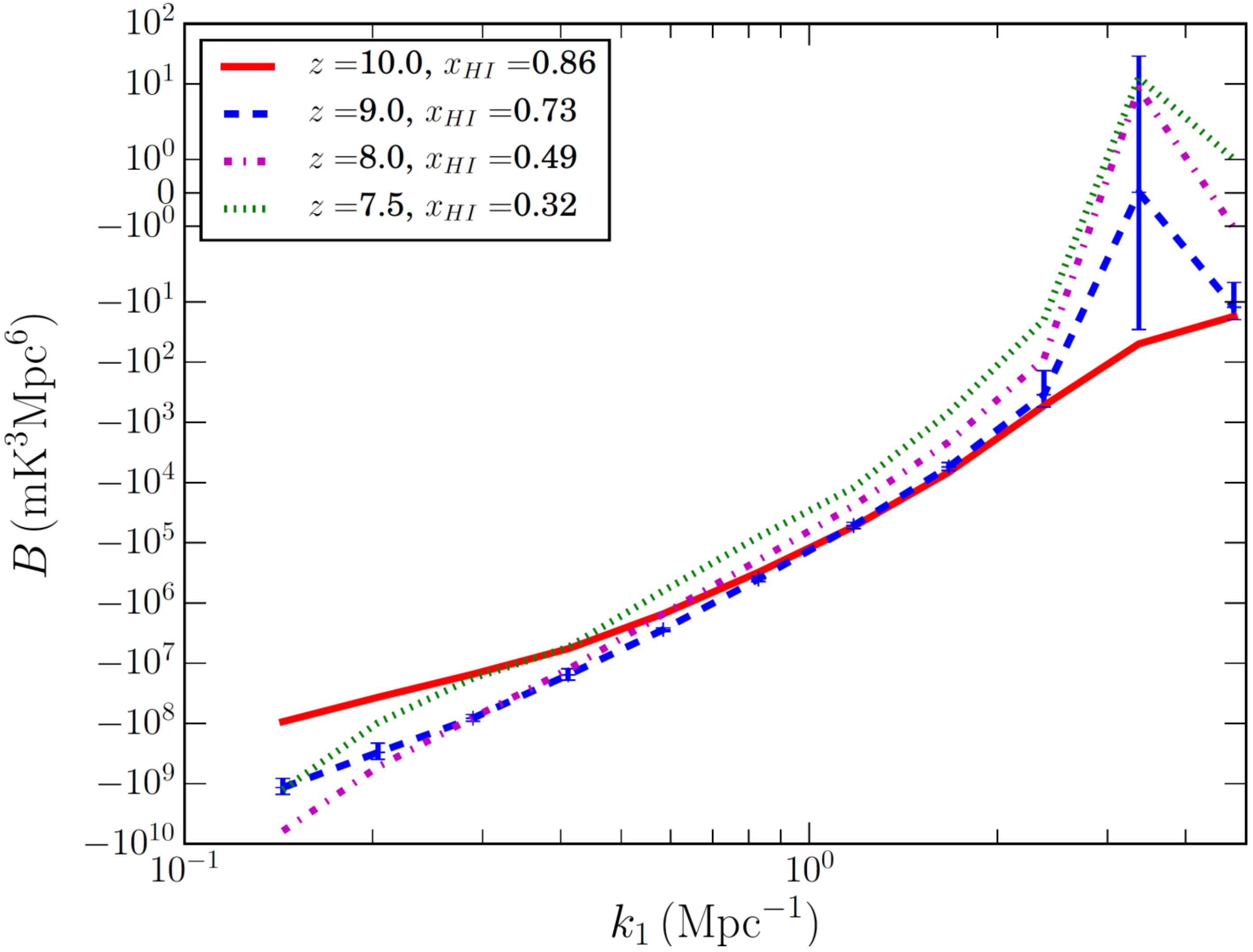
- Bispectrum may distinguish between different reionization source models through the 21-cm topologies produced by them

Simulated EoR 21-cm signal



- PM N-body density field with mass resolution $\sim 10^8\ M_\odot$
- Identify halos (FoF algorithm) as the host of EoR sources
- Use excursion set based semi-numerical method (for a specific source model) to identify ionized regions

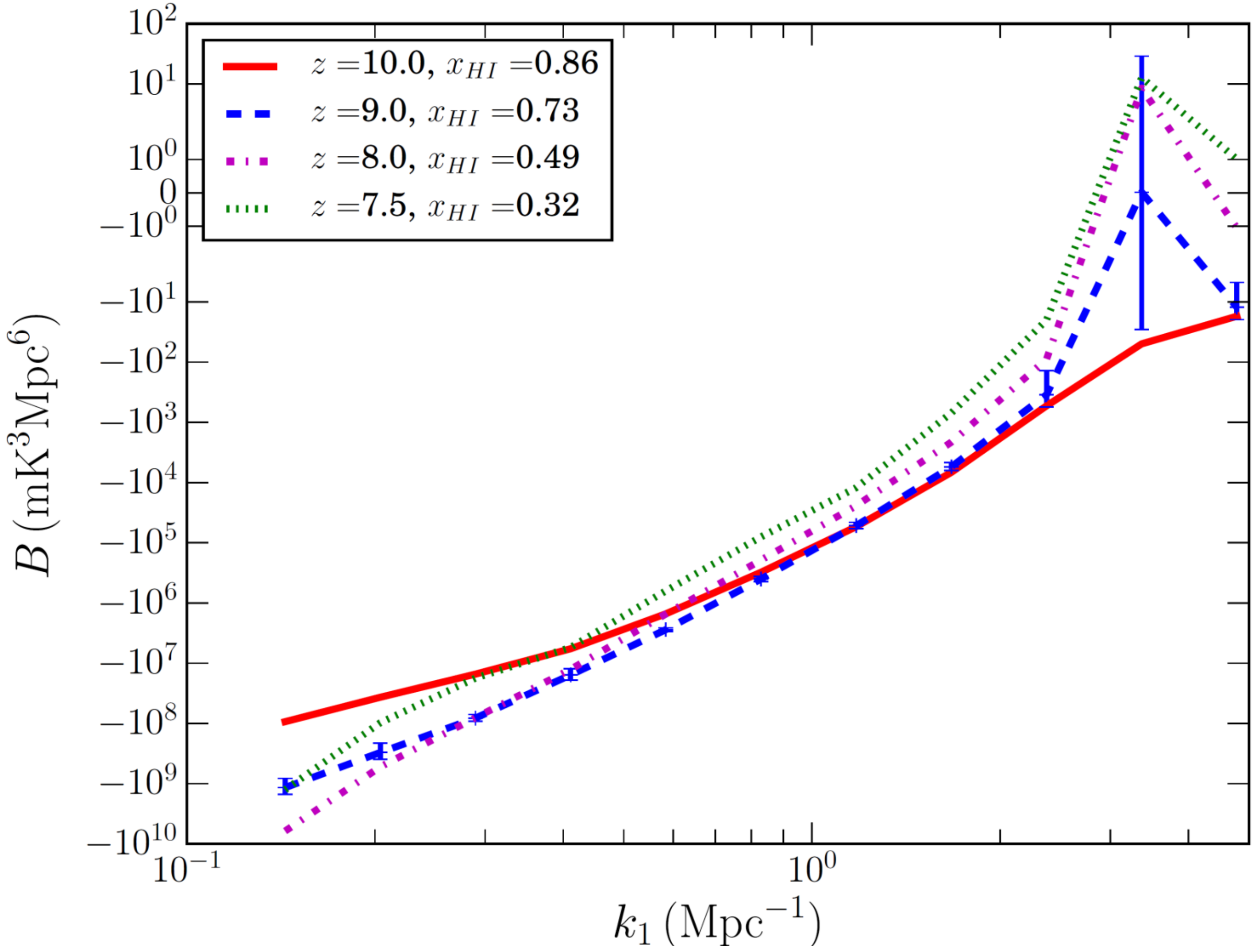
EoR 21-cm bispectrum
(in real space)



Majumdar, Pritchard, Mondal, Watkinson et al., arXiv:1708.08458

Equilateral triangles

EoR 21-cm bispectrum (in real space)

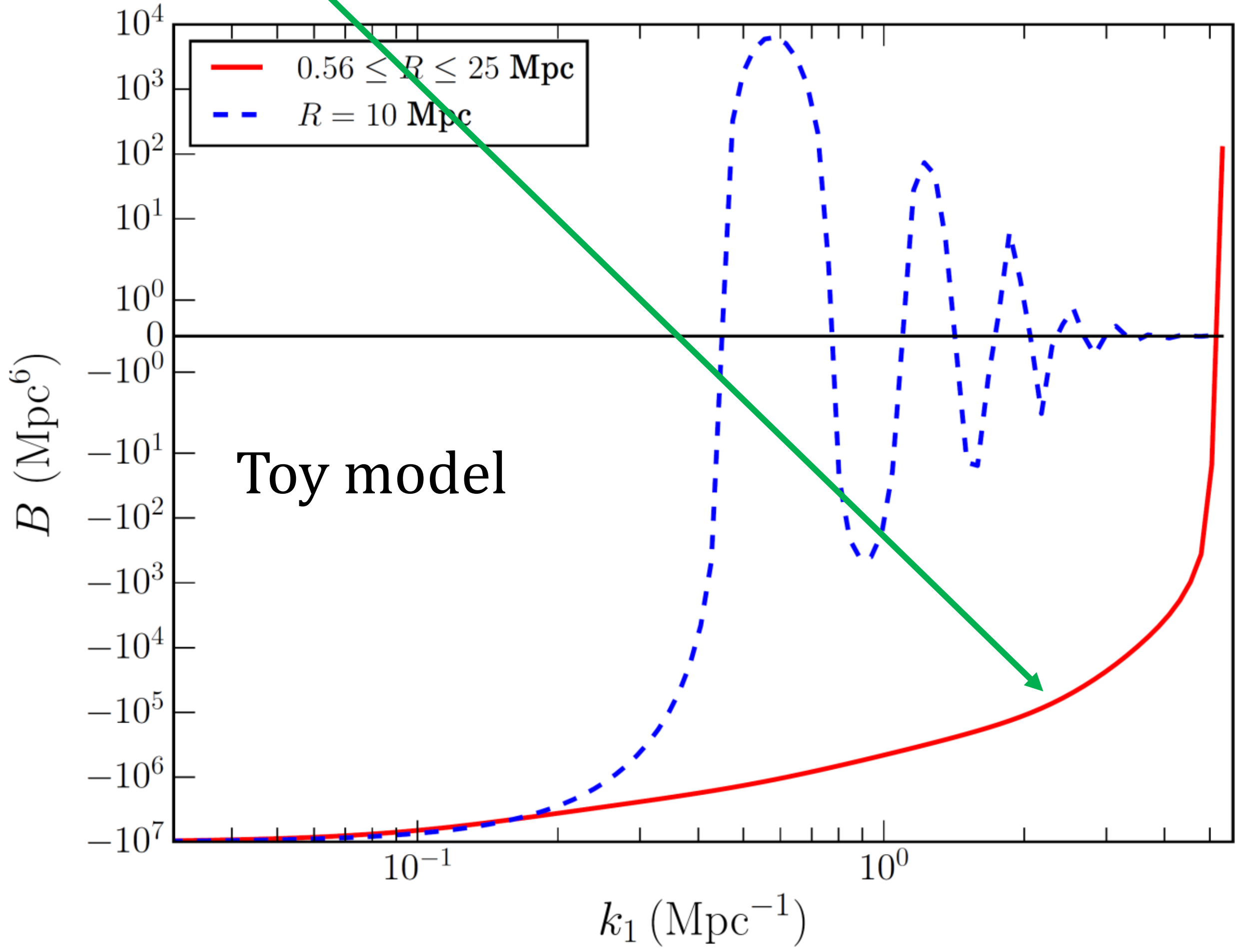


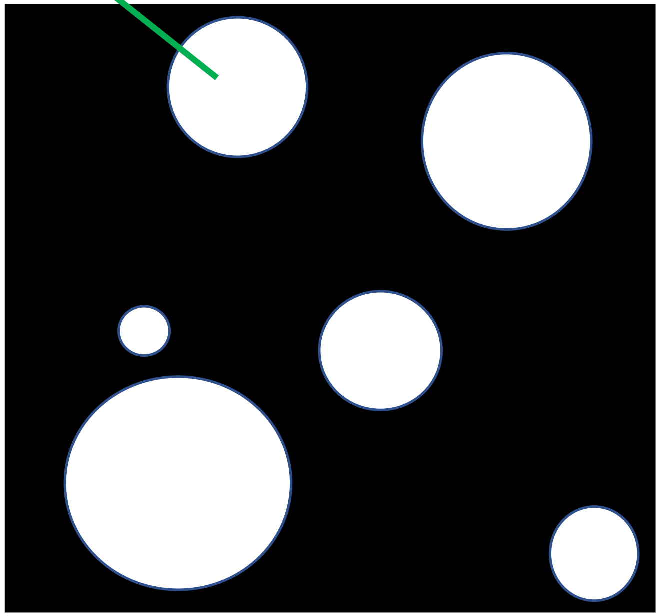
Equilateral triangles

Majumdar, Pritchard, Mondal, Watkinson et al., arXiv:1708.08458

- EoR 21-cm bispectrum is real and negative
- Amplitude of B increases with decreasing x_{HI} at smaller k modes
- It shows power-law like features as a function of k

$$B_{\mathrm{H\,I}}(\mathbf{k}_1, \mathbf{k}_2, \mathbf{k}_3) \propto -\sum_a W(k_1 R_a) W(k_2 R_a) W(k_3 R_a)$$





Equilateral triangle

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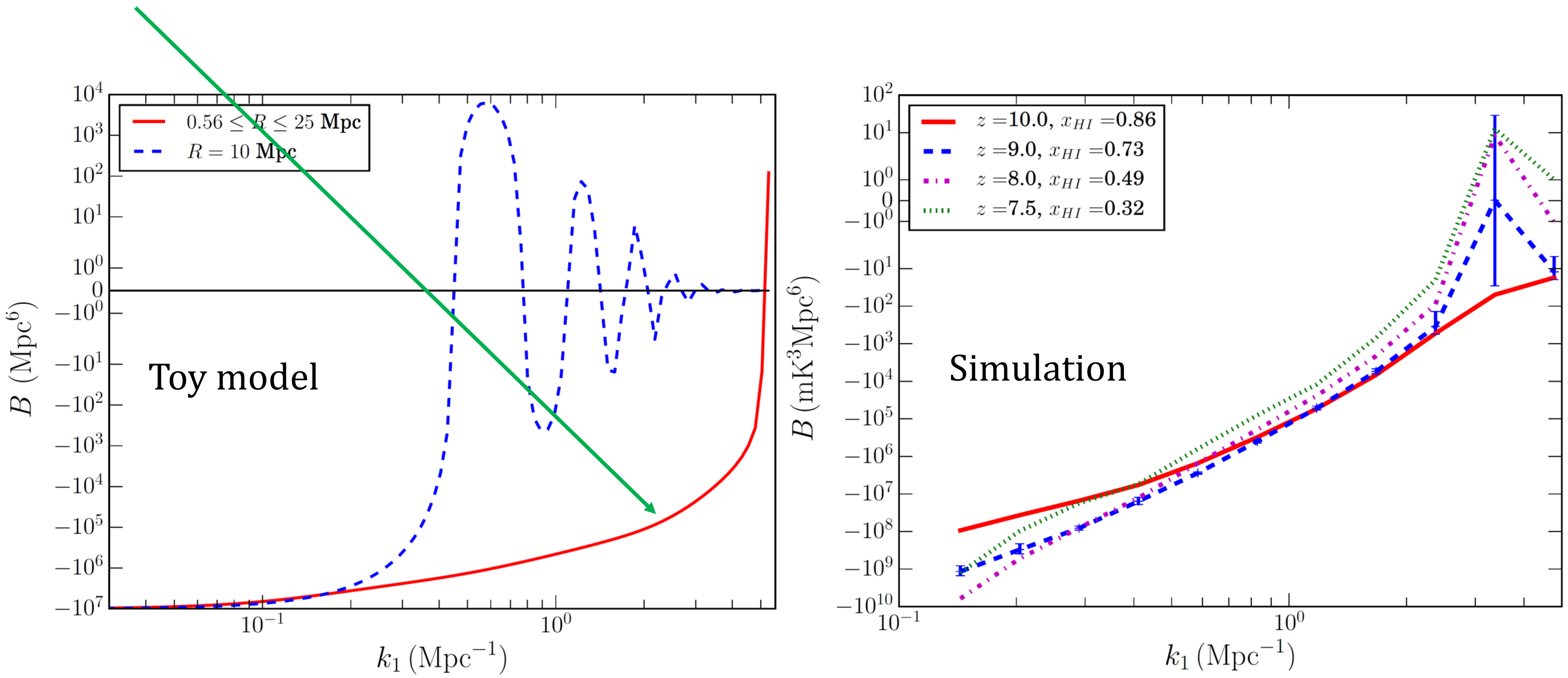
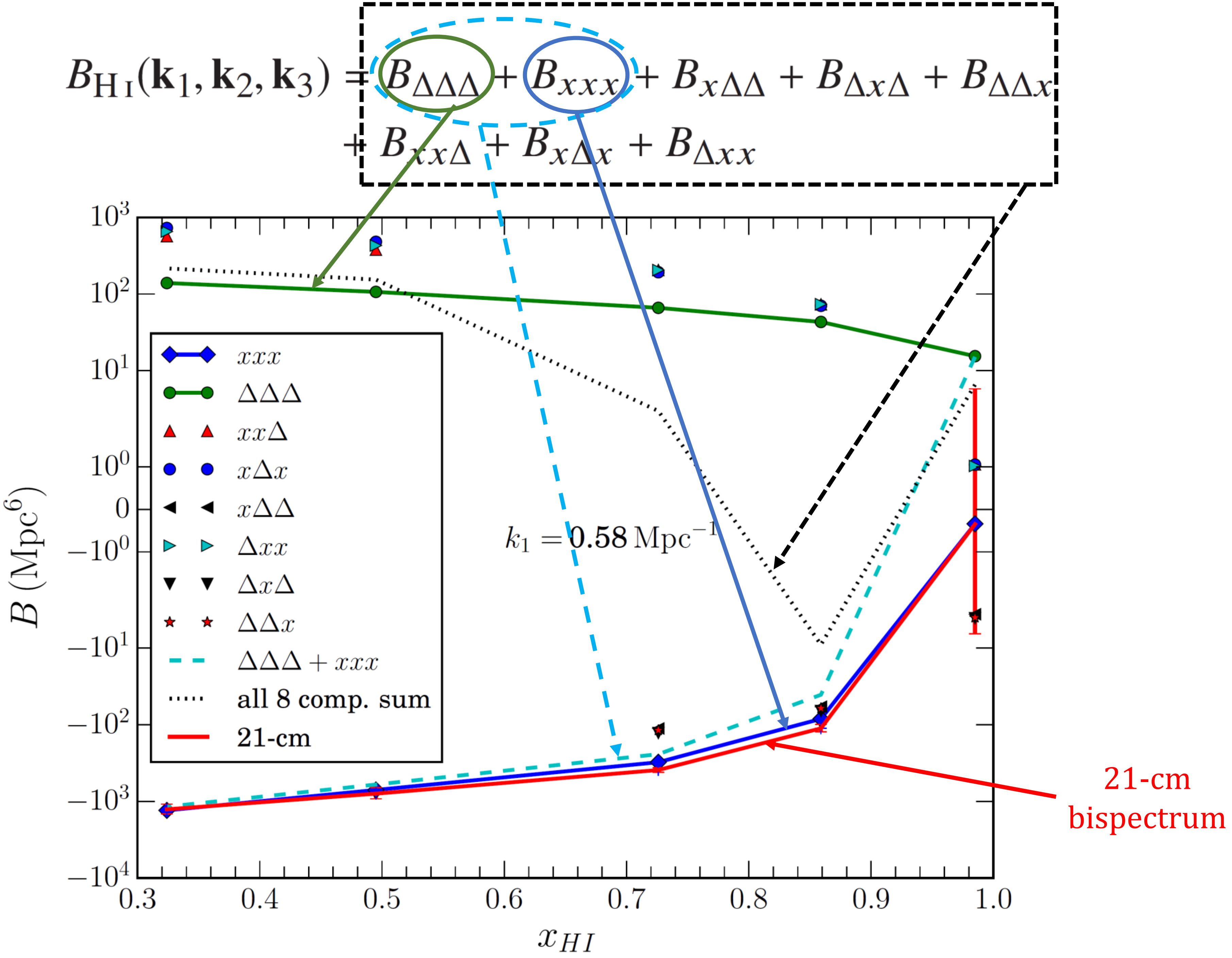
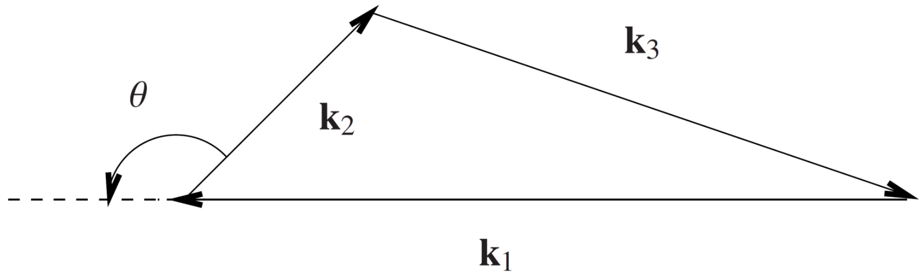


Equilateral triangle

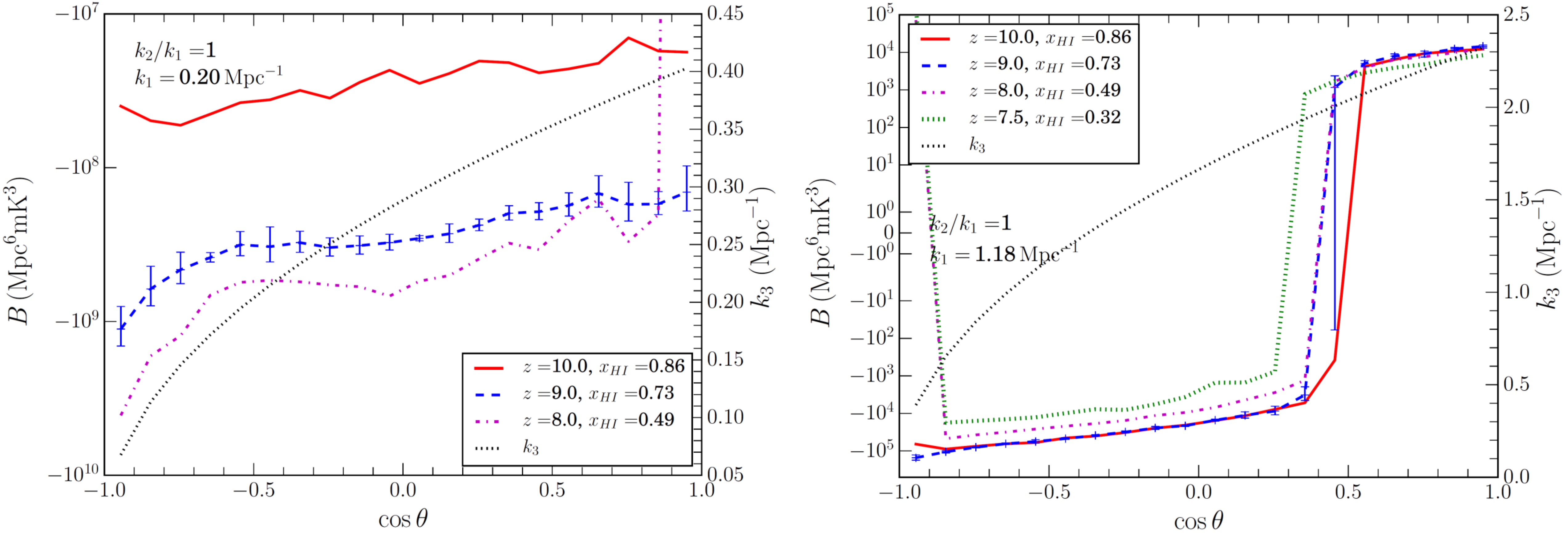
Components of HI bispectrum



EoR 21-cm bispectrum



$$\left|\vec{k}_2\right| = \left|\vec{k}_1\right|$$

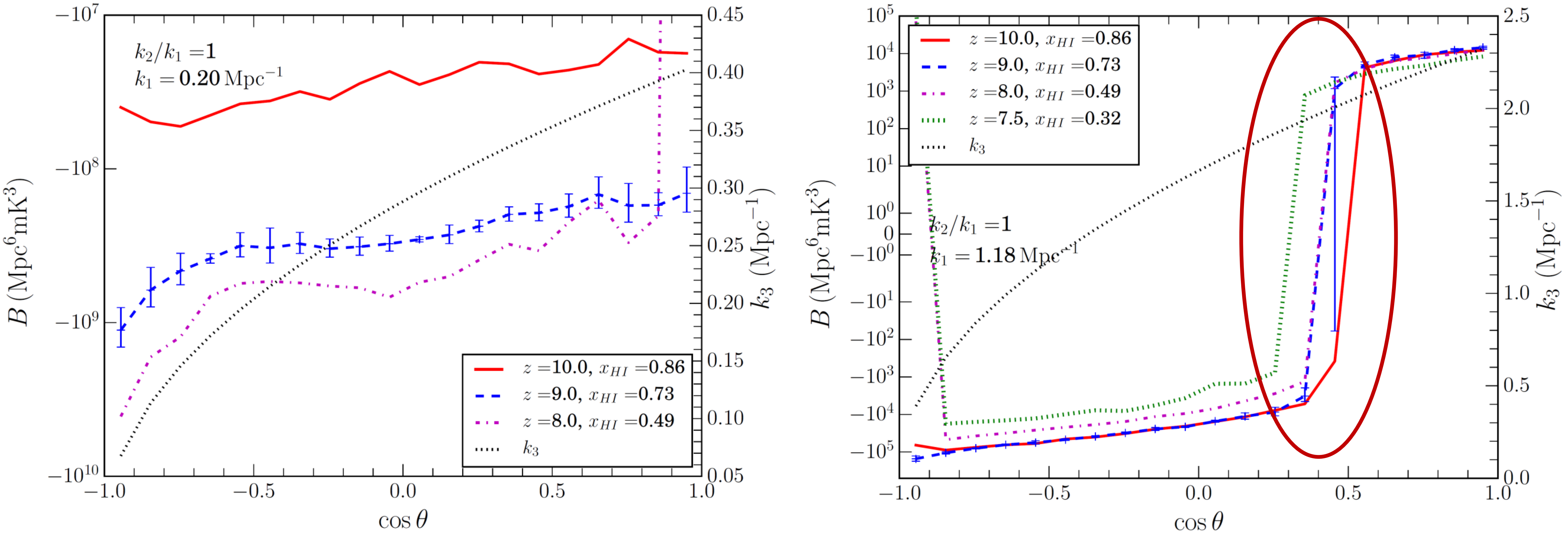


Isosceles triangles

Majumdar, Pritchard, Mondal, Watkinson et al., arXiv:1708.08458

EoR 21-cm bispectrum

$$\left|\vec{k}_2\right| = \left|\vec{k}_1\right|$$

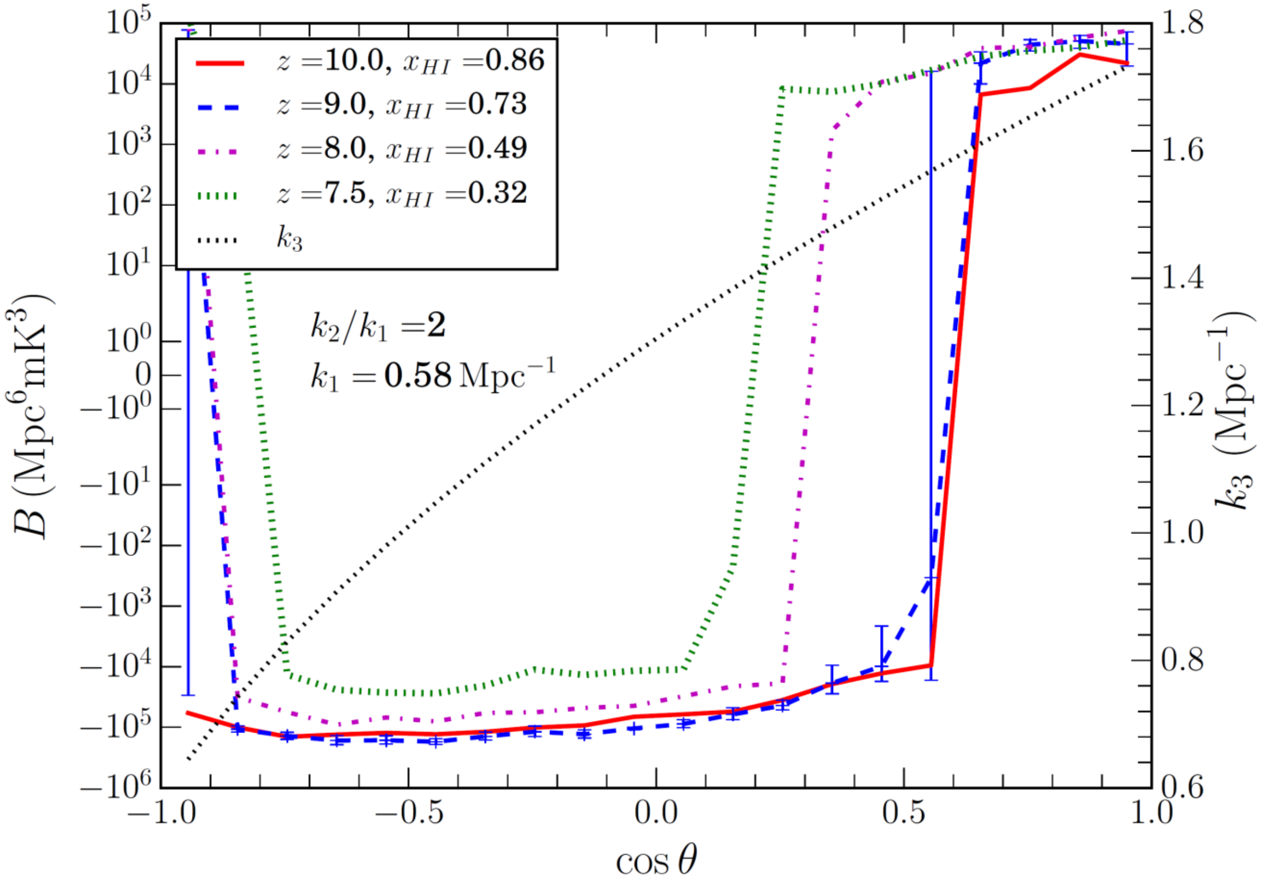


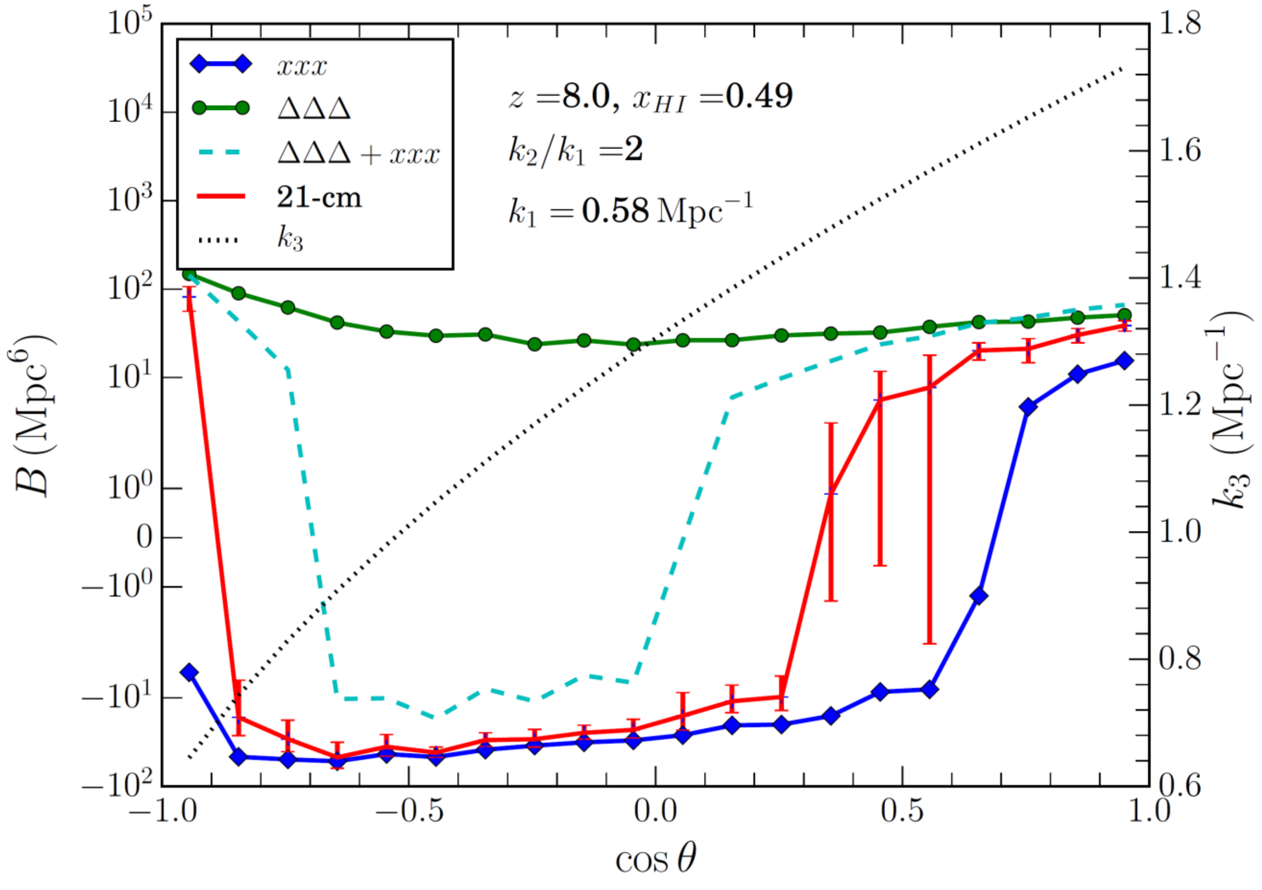
Isosceles triangles

Majumdar, Pritchard, Mondal, Watkinson et al., arXiv:1708.08458

EoR 21-cm bispectrum

$$\left|\vec{k}_2\right| = 2\left|\vec{k}_1\right|$$



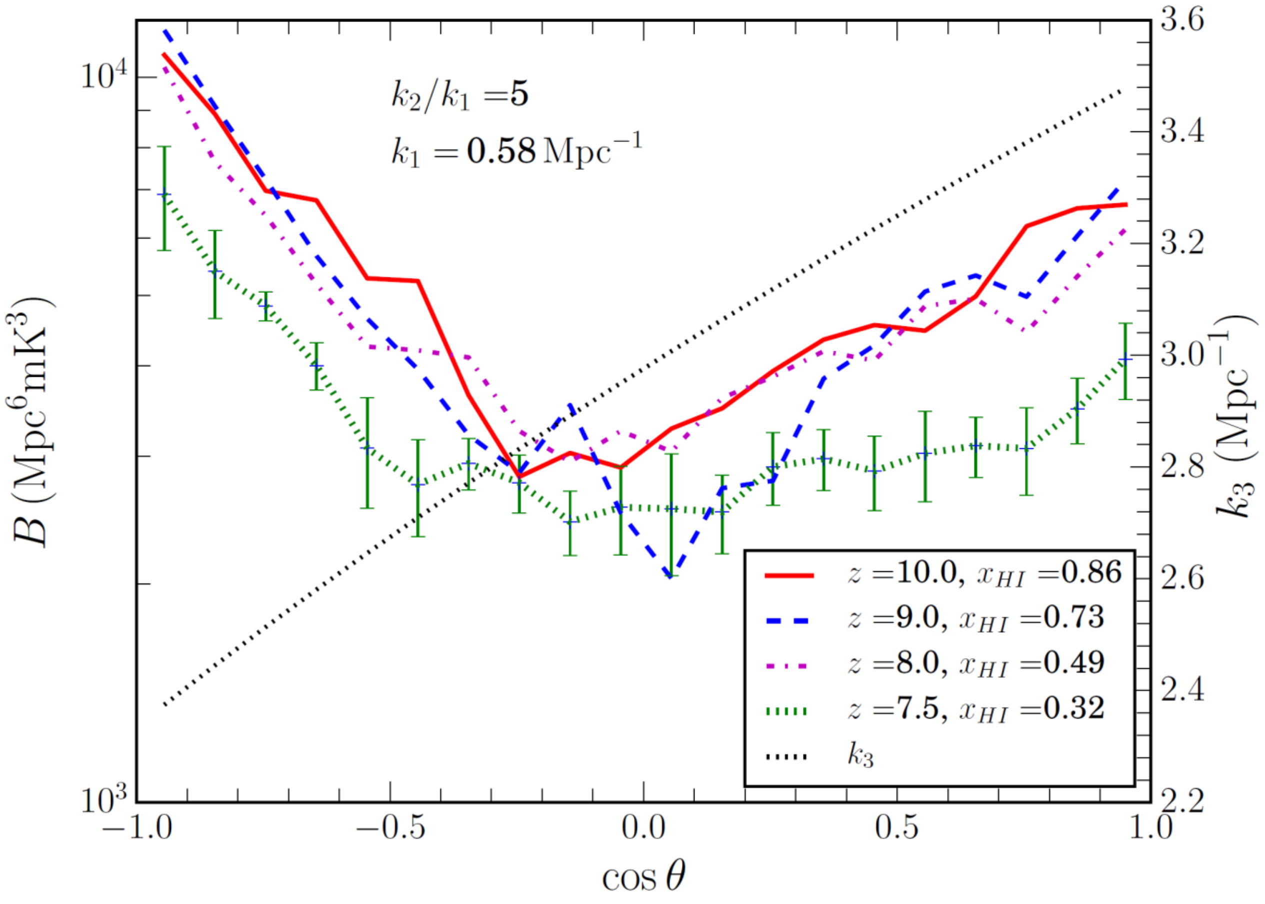


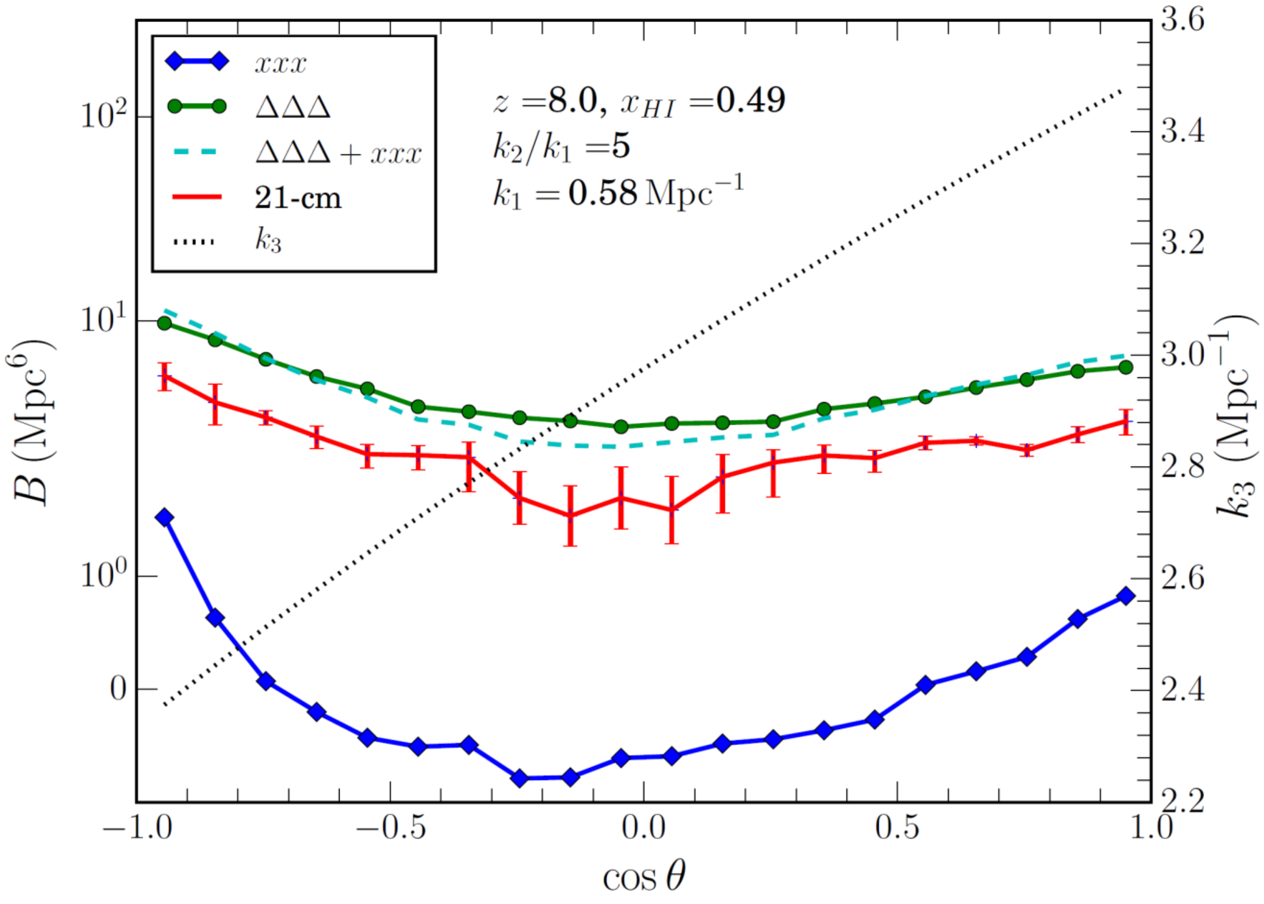
Asymmetric triangles

Majumdar, Pritchard, Mondal, Watkinson et al., arXiv:1708.08458

EoR 21-cm bispectrum

$$\left|\vec{k}_2\right| = 5\left|\vec{k}_1\right|$$





Asymmetric triangles

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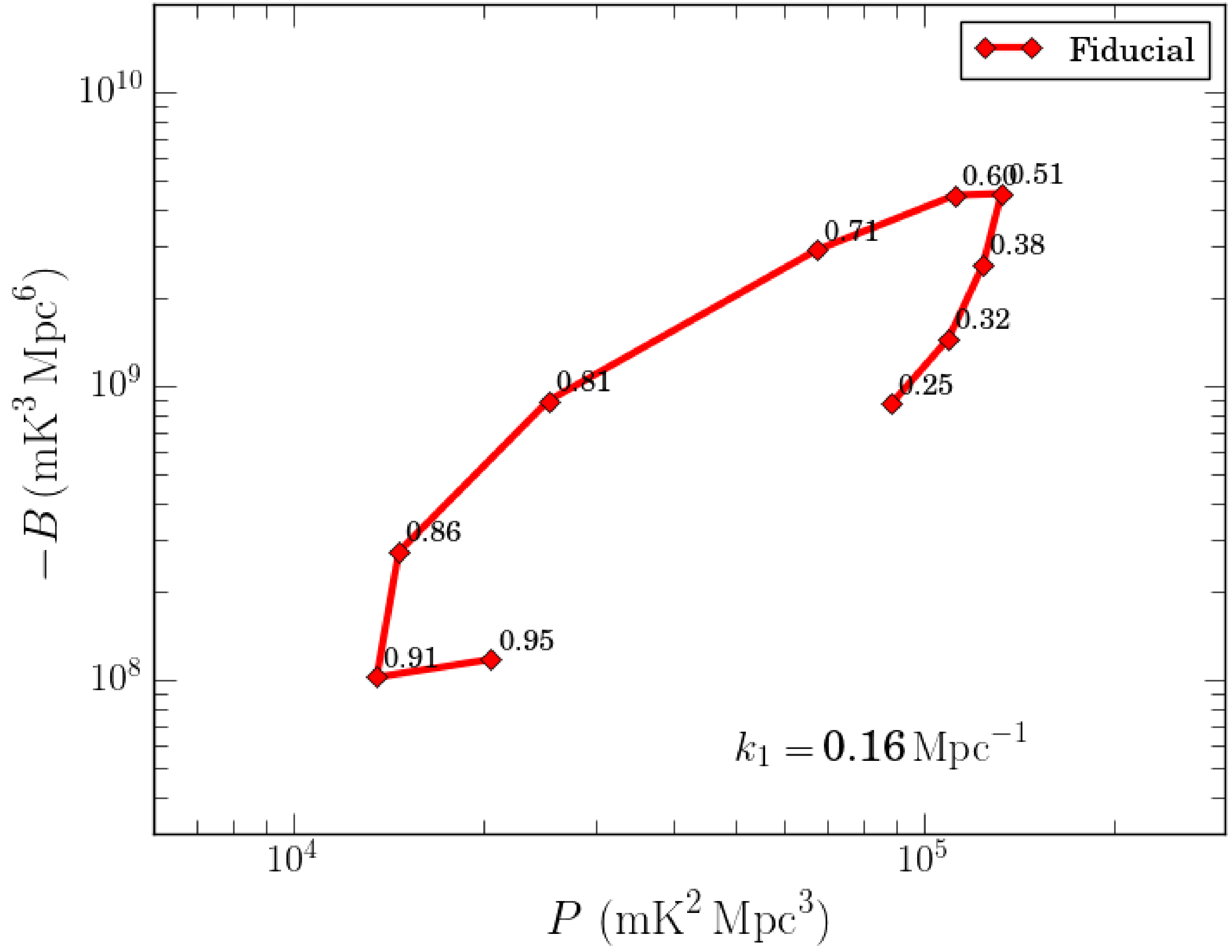
Evolution of the signal in $P(k) - B(k,k,k)$ space



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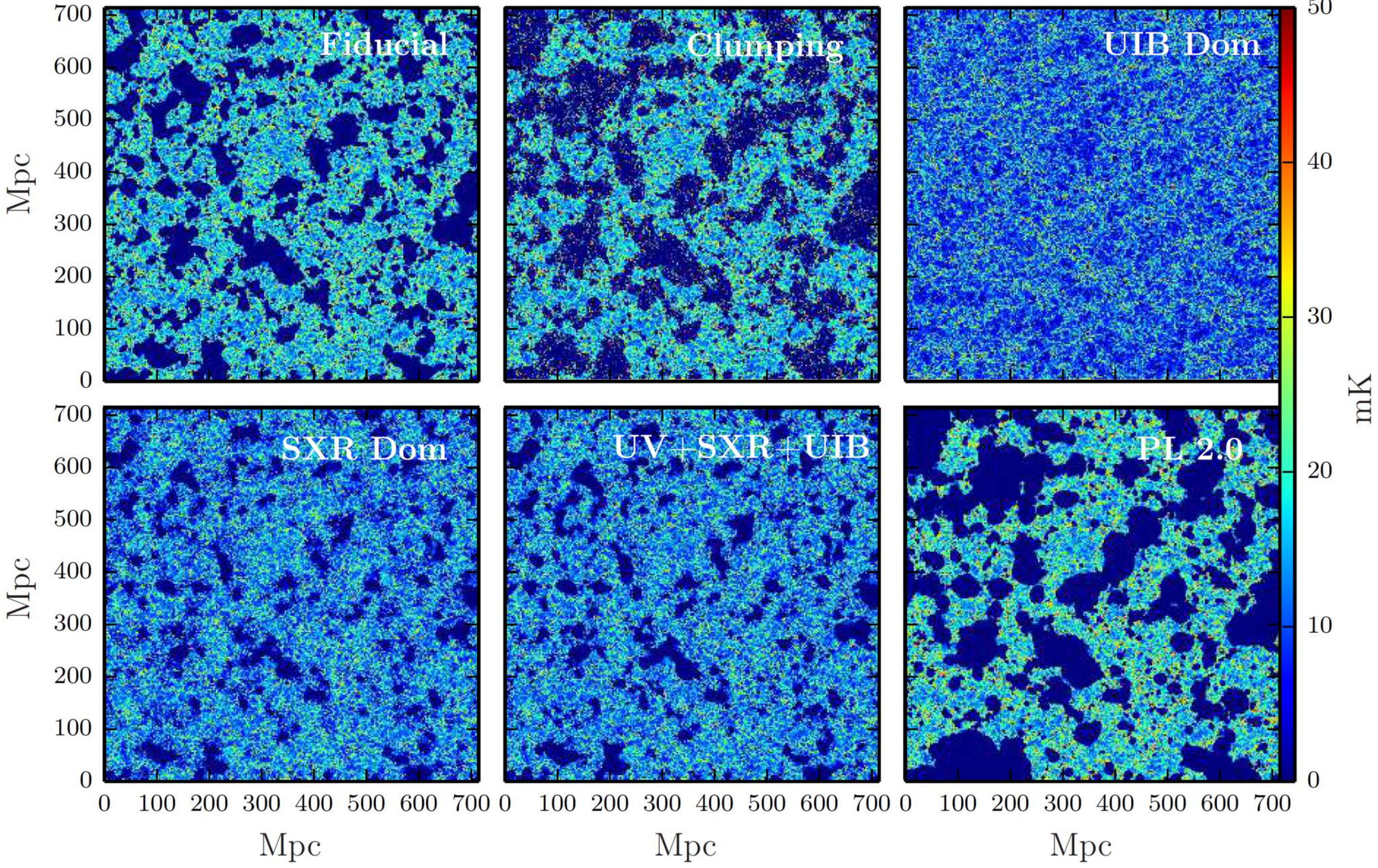
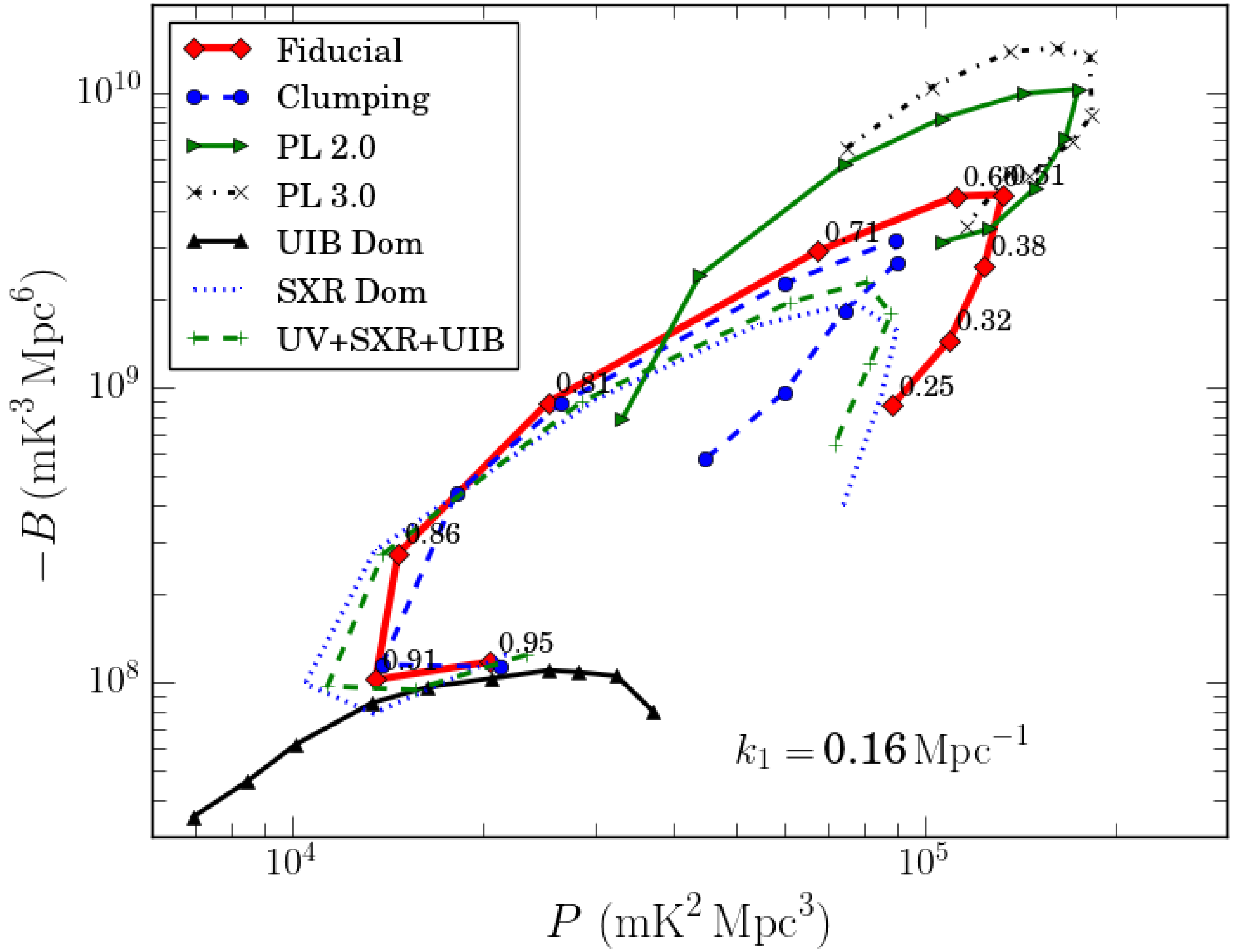
21-cm maps for differnt source models



Evolution of the signal in $P(k) - B(k,k,k)$ space



Summary:

- Real space 21-cm bispectrum for triangles with *small k* (s) are ---
  a) **negative**, b) $\propto \mathbf{x_i^3}$, c) **follows $\boldsymbol{x_{HI}}$ bispectrum**
- A simple toy model of x_{HI} fluctuations with spherical ionized regions can mimic this behavior
- Bispectra for isosceles and asymmetric triangles with **intermediate and large *k*** modes show a **change in sign** from **negative to positive**
- The specific set of ***k*** **modes** for which this **sign change** first appears depends on the **global $\boldsymbol{x_{HI}}$**
- A positive 21-cm bispectrum probes a modulated version of the underlying **matter bispectrum**
- A bispectrum with a distinctive **shape** and **sign** (and its **change**) as a function of $\cos\theta$ can be used as a **confirmation for the EoR 21-cm signal detection**
- The evolutionary tracks of the signal in $\boldsymbol{P(k) - B(k,k,k)}$ **phase space** can be used to put robust **constrain** on the **EoR parameters**