The Constraint of Void Bias on primordial non-Gaussianity

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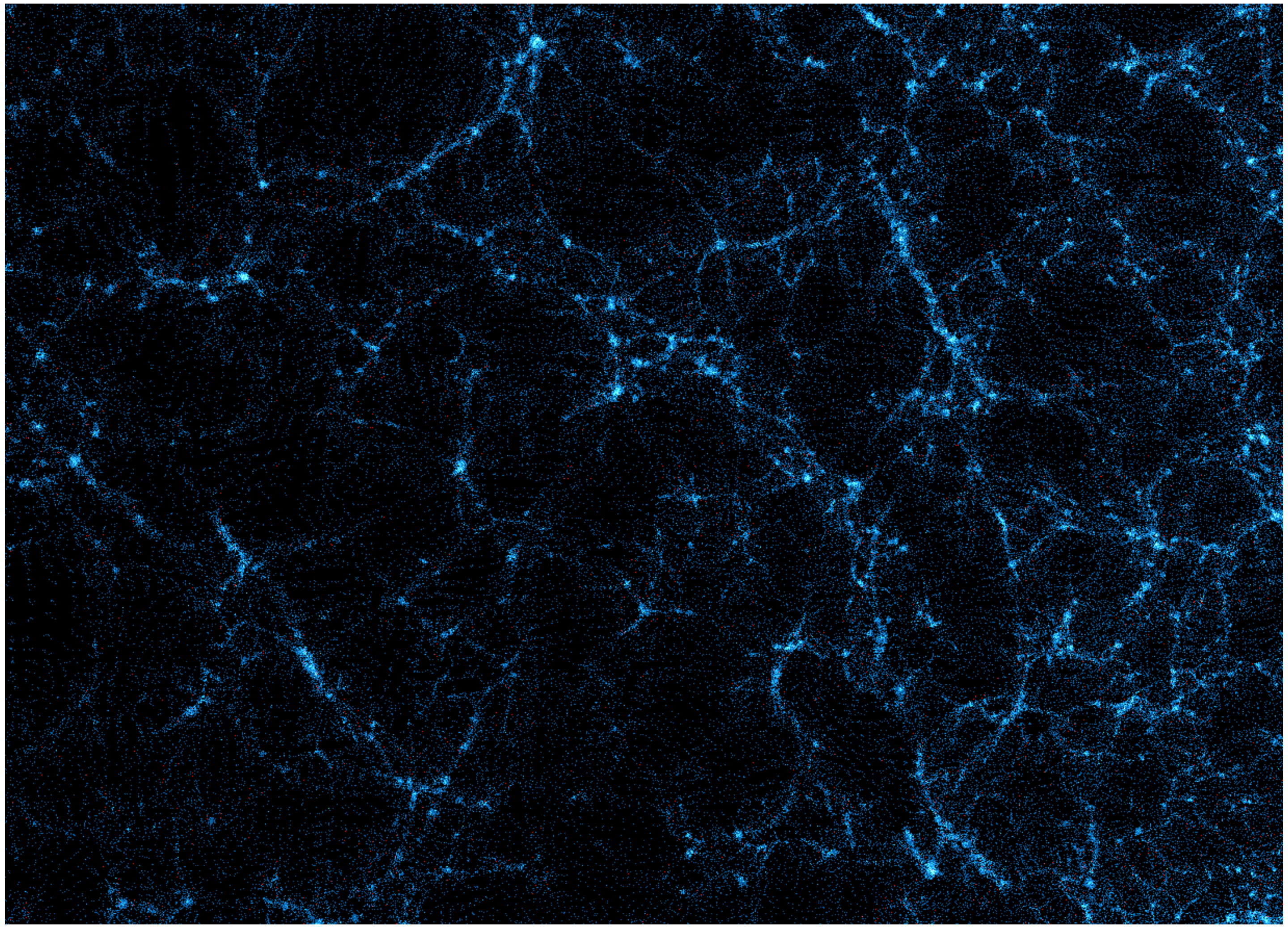
Cosmic Voids

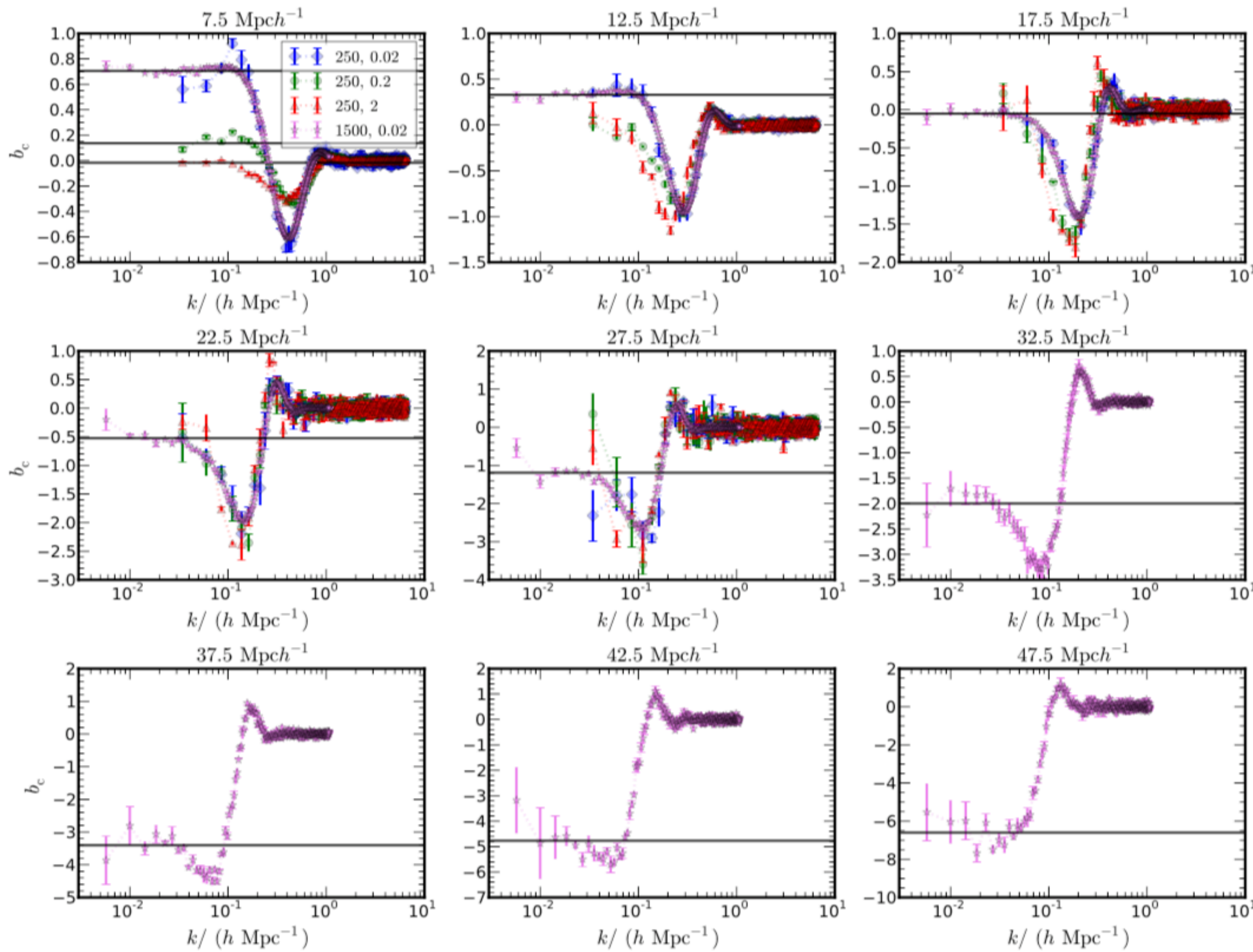
- Voids are large under density region, occupy largest volume of the cosmic web, need large volume to get a good statistics
- Hold the information complementary to the halo clustering
- Easy to see by eyes, hard to define. Many algorithms proposed, define similar by not identical voids



Cross bias of void

- Voids as large scale structure tracers

$$b_c = \frac{P_{vm}}{P_m}$$

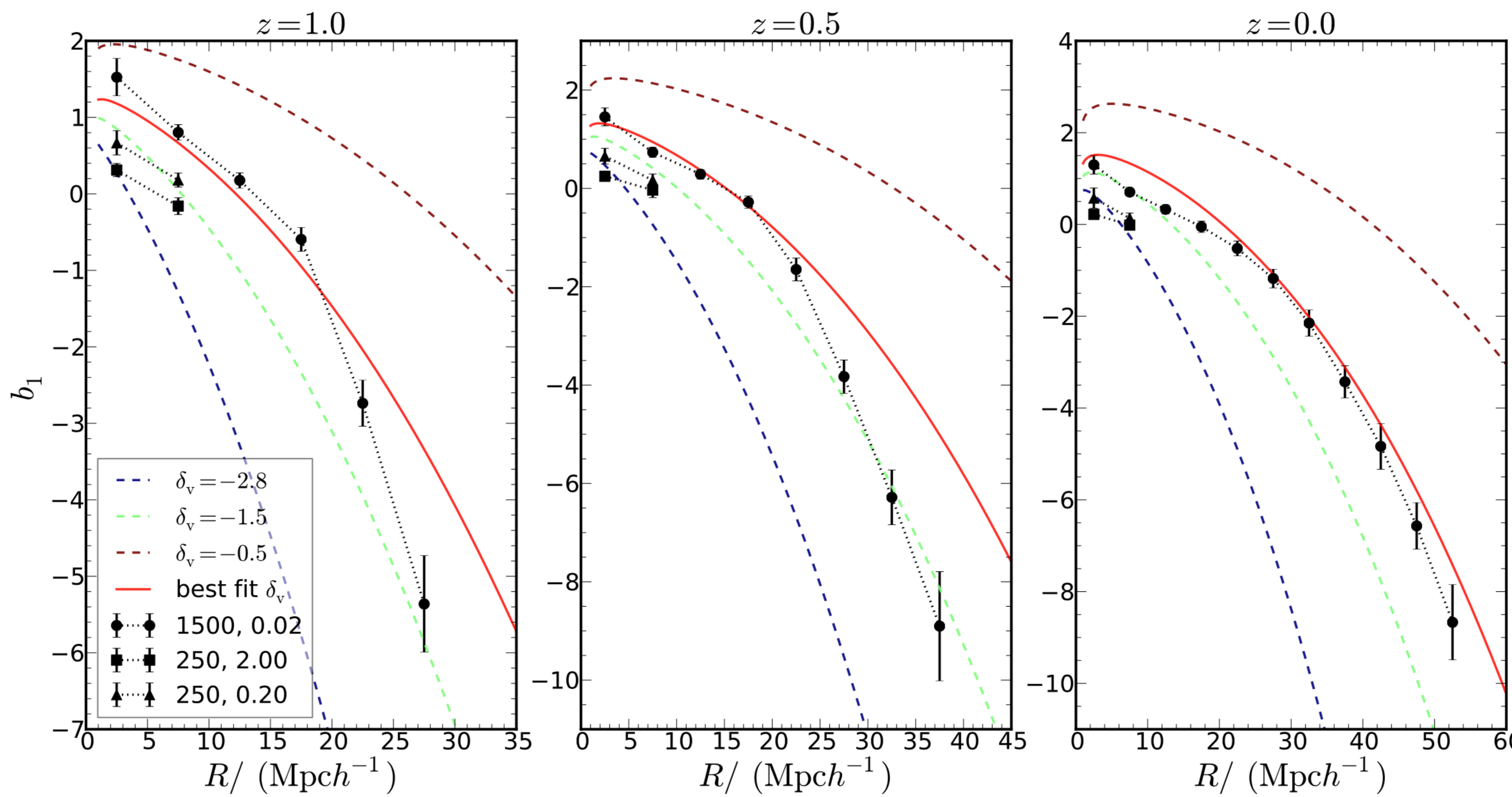


KCC, Hamaus, Desjacques, 2014

Void bias measurement from simulation

- When δ_v is taken as a free parameter, the void bias can approximately fit the simulation measurement. Best fit δ_v~ -1.

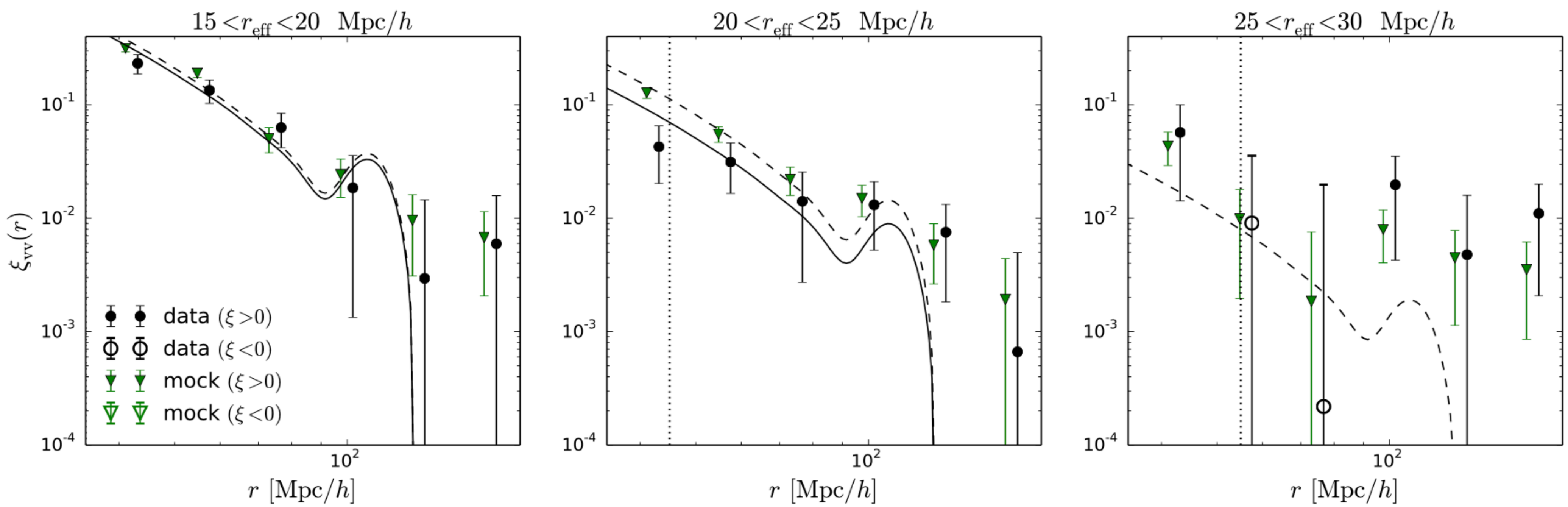
$$b_{\rm v}^{\rm G} = 1 + \frac{\nu^2 - 1}{\delta_{\rm v}} + \frac{\delta_{\rm v}\mathcal{D}}{4\delta_{\rm c}^2\nu^2}.$$

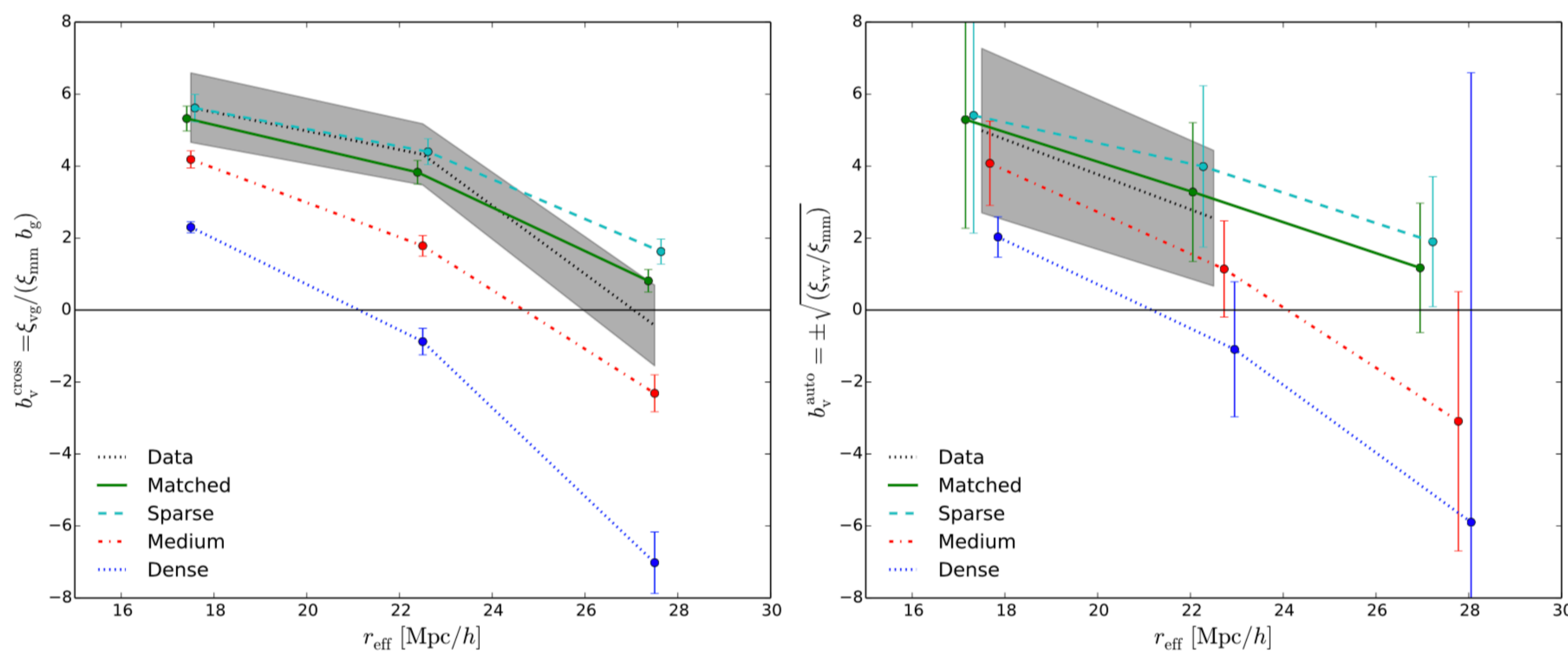


KCC, Hamaus, Desjacques, 2014

The void bias measurement from the SDSS data

- Using the SDSS data, Clampitt et al, 1507.08031 measured the void bias parameters in the configuration space.



- 

- We can measure the void bias!!

Local Primoridal non-Gaussianity (PNG)

- The initial density perturbation in the early universe is very close to Gaussian
- Various models of inflation predict small amount of PNG.
- The local PNG model often arises from the multi-field inflation.
- In local PNG, the Bardeen potential is

$$\Phi = \phi + f_{\rm NL}(\phi^2 - \langle\phi^2\rangle)$$

- Measurement of the nonlinear parameter gives important insight on the inflation physics, it has been tightly constrained by the Planck mission's bispectrum measurement

$$f_{\rm NL} = 0.8 \pm 5.0$$

Scale-dependent halo bias

- Dalal et al, 0710.4560, discovered that in the local PNG model, the large-scale halo bias exhibits scale-dependent correction
- In the Gaussian case, there is no coupling between the large-scale mode and the small scale mode.
- Local PNG model introduces coupling btw the small-scale mode with the large-scale one
- This coupling modulates the small-scale halo formation

The PNG bias as a response of the halo mass function n to the local value of σ_8 (Slosar et al, 0805.3580)

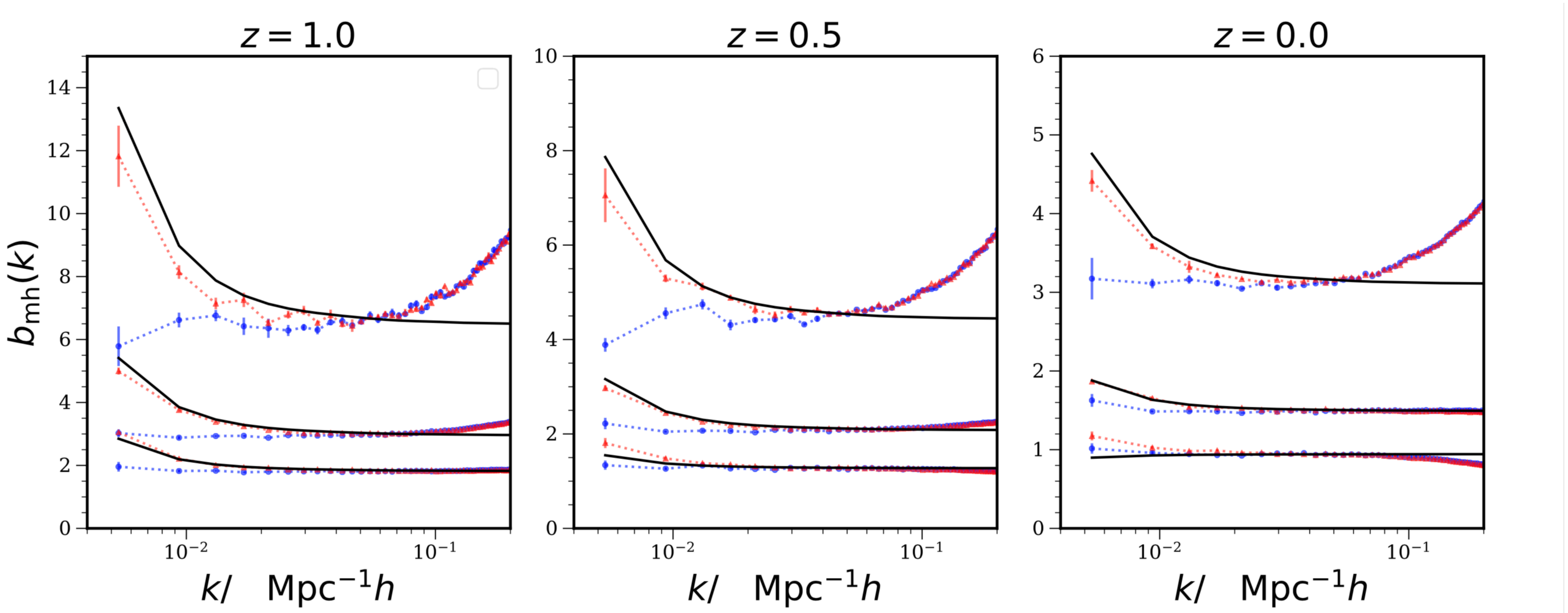
$$
\begin{aligned}
b^{\rm NG} &= \frac{1}{n} 2 f_{\rm NL} \mathcal{M}^{-1} \frac{\partial n}{\partial \ln \sigma_8(\boldsymbol{x})}, \\
\mathcal{M}(k) &= \frac{2}{3} \frac{c^2 k^2 T(k) D}{\Omega_{m0} H_0^2}.
\end{aligned}
$$

Scale-dependent halo bias

- Assuming universal mass function, the PNG halo bias can be written as

$$b_{\rm h}^{\rm NG} = \frac{3 f_{\rm nl} \Omega_{\rm m0} H_0^2}{k^2 T(k) D(z)} \delta_{\rm c} (b_{\rm h}^{\rm G} - 1).$$

- This prescription gives ~10% accuracy compared with simulation



LSS constraint on $f_{\rm NL}$

- The PNG signals is on large scale, less likely to be contaminated by astrophysical effects. However, systematics like the stellar contamination can give false signals.

- Using the multiple galaxies data sample, Giannantonio et al, 1303.1349, got $f_{\rm NL}$= 5 +- 21. From quasar samples, Leistedt et al, 1311.2597 got -39< $f_{\rm NL}$< 23

- Many studies suggest that the bound on $f_{\rm NL}$ is future experiments is expected to tightened by an order of magnitude or so, e.g. SPHEREx

- We explore the constraint on $f_{\rm NL}$ by including the clustering info from voids.

Simple scale dependent PNG bias

- If we take the simple SvDW void size distribution

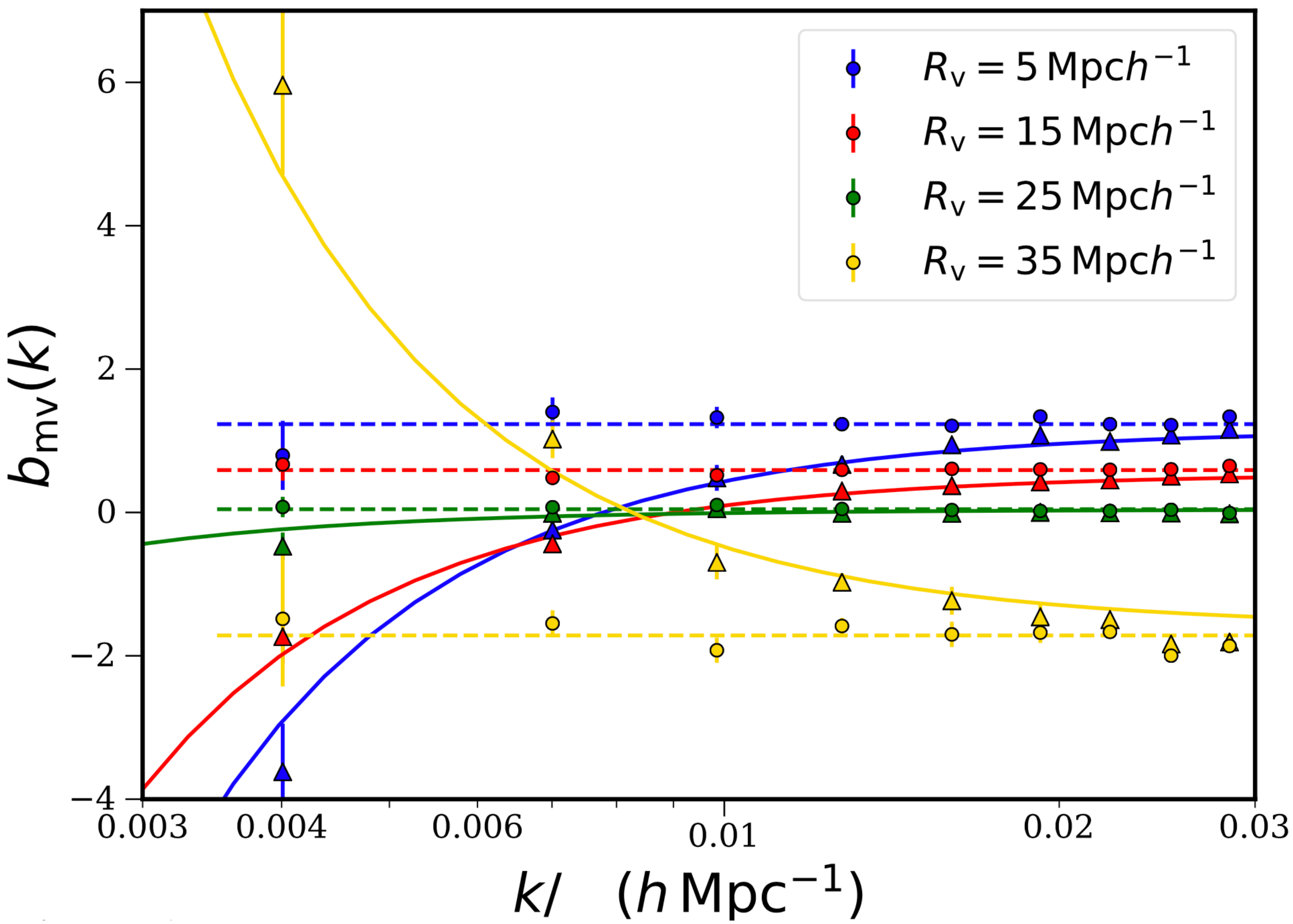
$$\mathcal{F}(\nu, \delta_{\rm v}, \delta_{\rm c}) = \sqrt{\frac{2}{\pi}} \exp\Big(-\frac{\nu^2}{2}\Big) \exp\Big(-\frac{|\delta_{\rm v}|}{\delta_{\rm c}}\frac{\mathcal{D}^2}{4\nu^2} - 2\frac{\mathcal{D}^4}{\nu^4}\Big)$$

- Scale dependent bias
- $$b_{\rm v}^{\rm NG}(k) = \frac{3 f_{\rm NL} \Omega_{\rm m0} H_0^2}{k^2 T(k) D(z)} \left(\nu^2 - 1 - \frac{|\delta_{\rm v}|\mathcal{D}^2}{2\delta_{\rm c}\nu^2} - \frac{8\mathcal{D}^4}{\nu^4}\right).$$
- In the high peak limit

$$b_{\rm v}^{\rm NG} = \frac{3 f_{\rm NL} \Omega_{\rm m0} H_0^2}{k^2 T(k) D(z)} \delta_{\rm v} (b_{\rm v}^{\rm G} - 1).$$

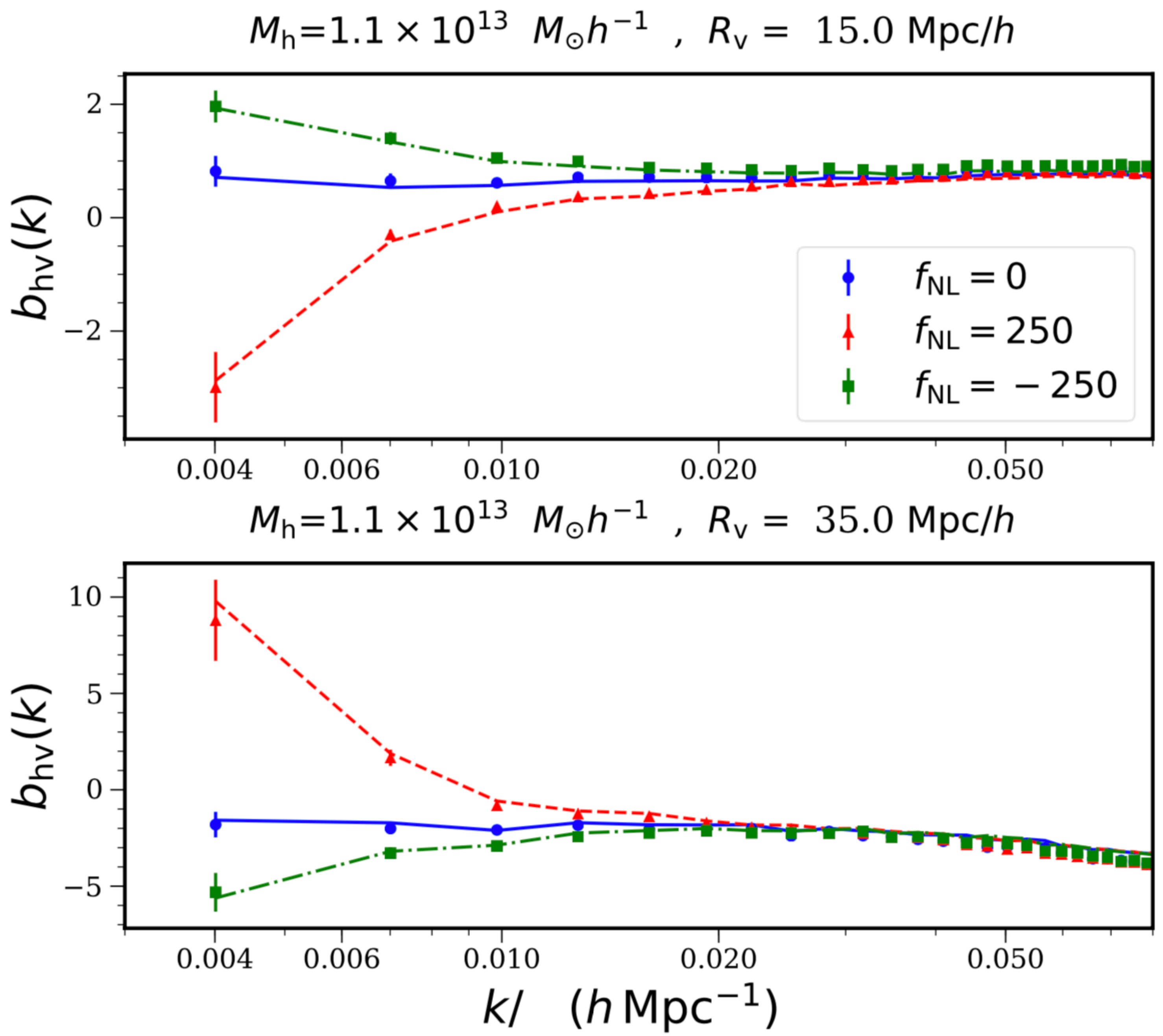
PNG void bias

- The PNG void bias shows scale dependent bias at low k
- $\frac{d \ln n}{d \ln \sigma_8}$ gives accurate prediction



Halo-void cross power spectrum

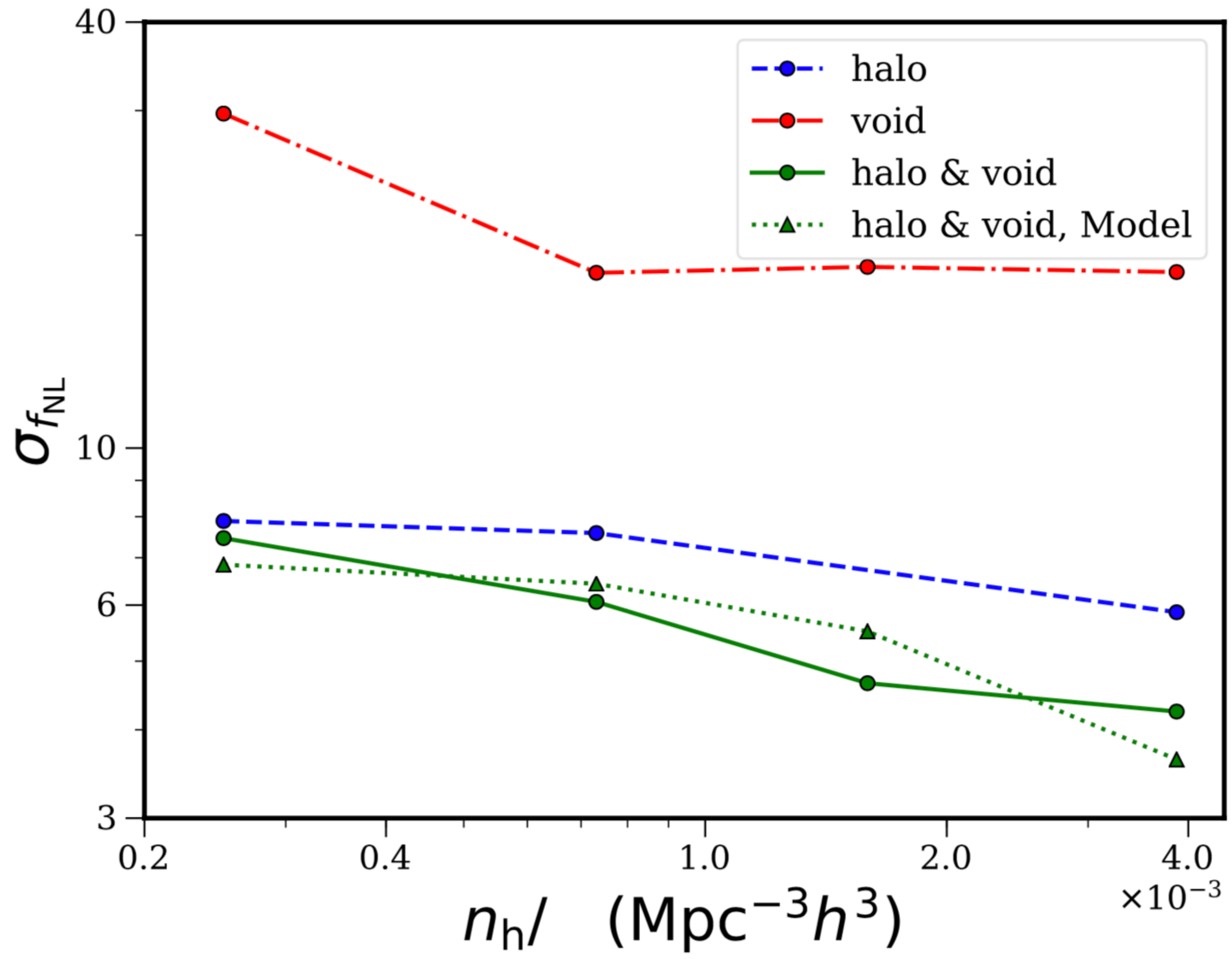
- The halo-void cross power spectrum probes $b_v b_h$



Constraint on f_NL from void clustering

- For void clustering, the shot noise is the most serious issue
- When the number density of the sample tracer is sufficiently high, by adding void clustering, the constraint is substantially improved.

$$\sigma_{f_{\rm NL}} = \frac{1}{\sqrt{F_{f_{\rm NL} f_{\rm NL}}}}$$



Conclusion

- The Gaussian void bias approaches a constant on large scale, while the PNG voids exhibits scale dependent bias similar to halos
- $\frac{d\ \ln}{d\ \ln \sigma_8}$ prediction agrees with numerical measurement well
- When the tracer density is sufficient high, the constraining power from void clustering can be comparable to the halos