Halo velocity bias and its effects in RSD

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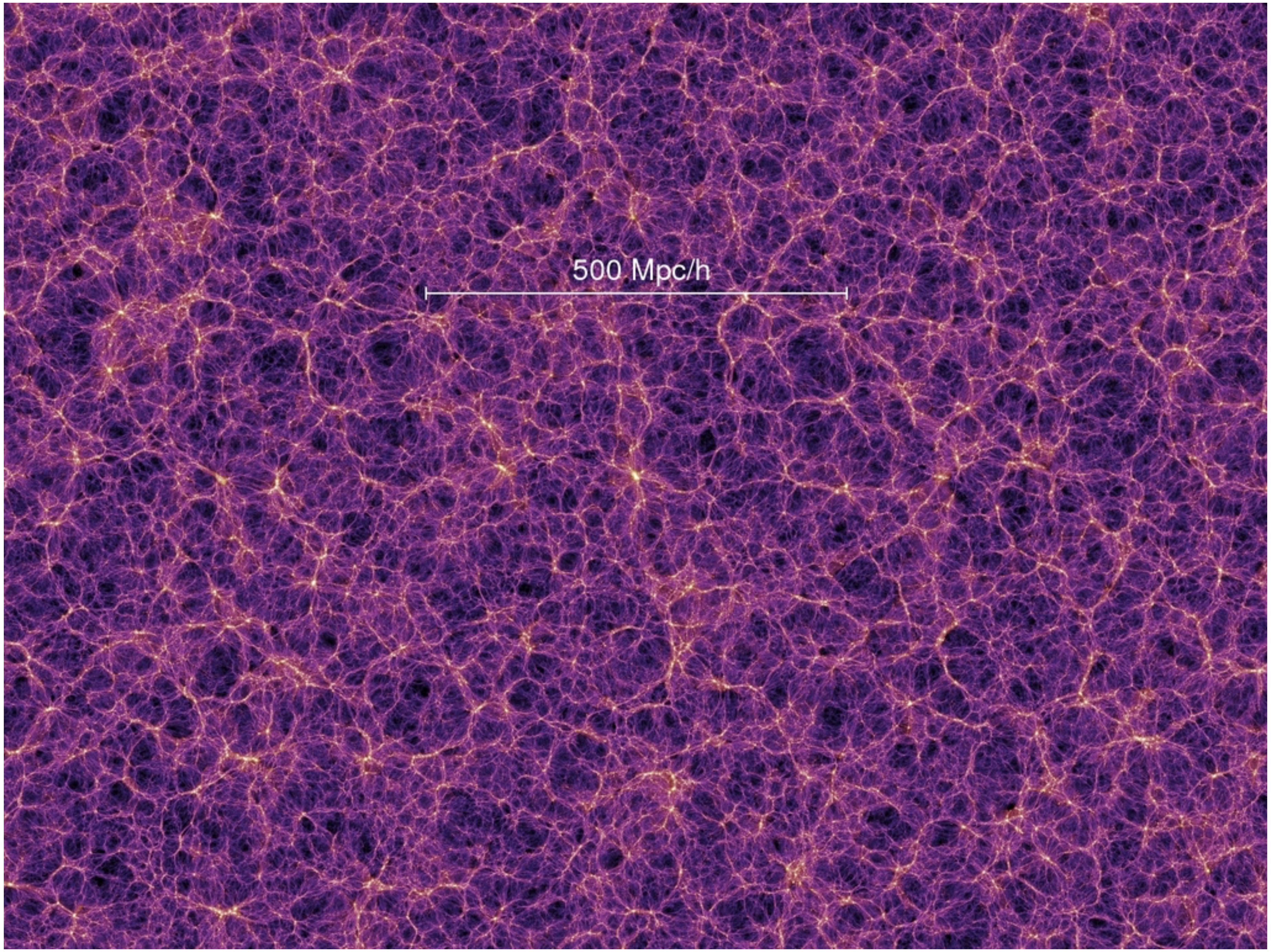
Halo(galaxy) velocity bias?

$$b_v(k) \equiv \frac{P_{v_h v_m}(k)}{P_{v_m v_m}(k)}$$

$$\boxed{b_v \times f\sigma_8}$$



Millennium Simulation

Peak model: proto-halos in the linear and Gaussian initial conditions.

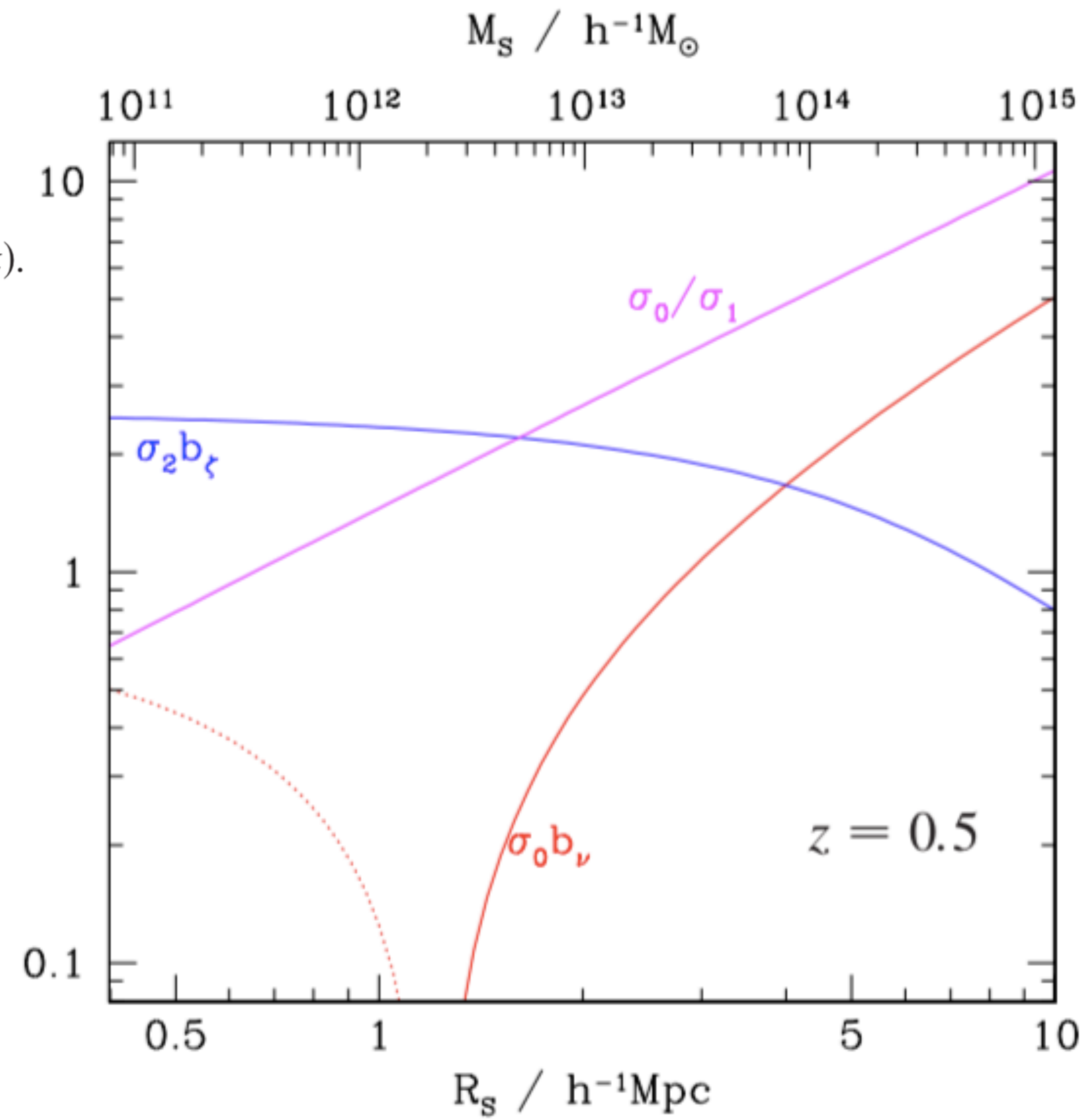
Peak velocity could be effectively expressed by nonlinear local bias model

$$\sigma_n^2 \equiv \frac{1}{2\pi^2}\int_0^\infty dk k^{2(n+1)} P_\delta(k,z)\hat{W}(k,R_S)^2.$$

$$\boldsymbol{v}_{\rm pk}(\boldsymbol{x}) = \boldsymbol{v}_S(\boldsymbol{x}) - \frac{\sigma_0^2}{\sigma_1^2}\nabla\delta_S(\boldsymbol{x}),$$

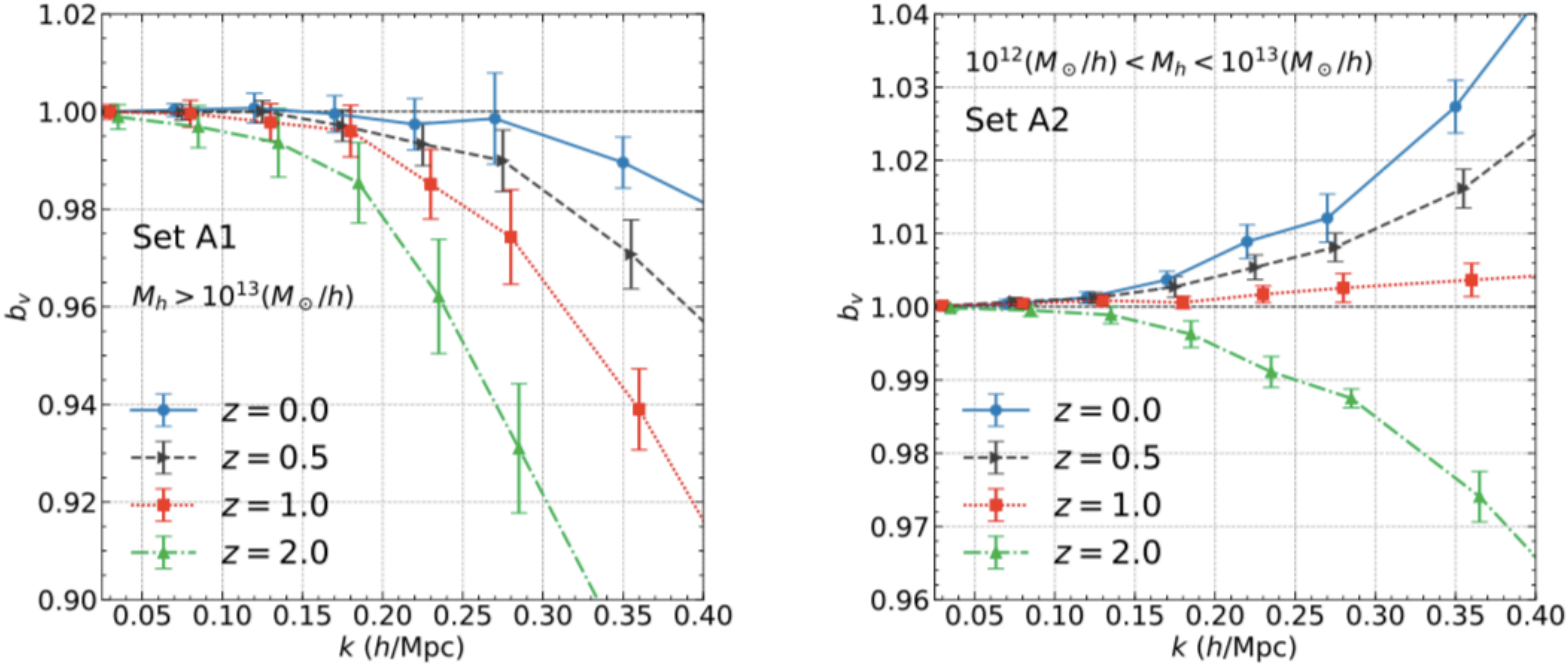
$$\theta_{\rm pk}(\boldsymbol{k}) = \left(1-\frac{\sigma_0^2}{\sigma_1^2}k^2\right)\hat{W}(k,R_S)\theta(\boldsymbol{k}) \equiv b_{\rm vel}(\boldsymbol{k})\theta_S(\boldsymbol{k}).$$

For 10^13 M_sun/h halos, the deviation from unity is ~5% at *k* = 0.1*h*/Mpc and larger at smaller scales.



Desjacques, Ravi K. Sheth, 0909.4544

However, for real FoF halos from simulations:



$$\xi_{(1+\delta_h)v_h v_m}(r) = \langle \boldsymbol{v}_h \cdot \boldsymbol{v}_m \rangle + \langle \delta_h \boldsymbol{v}_h \cdot \boldsymbol{v}_m \rangle$$

$$P_{(1+\delta_h)v_h v_m}(k) = P_{v_h v_m}(k) + B_{\delta_h v_h v_m}(k)$$

Chen et al. 1803.00728

Peak model: halos in the nonlinear and nonGaussian epochs

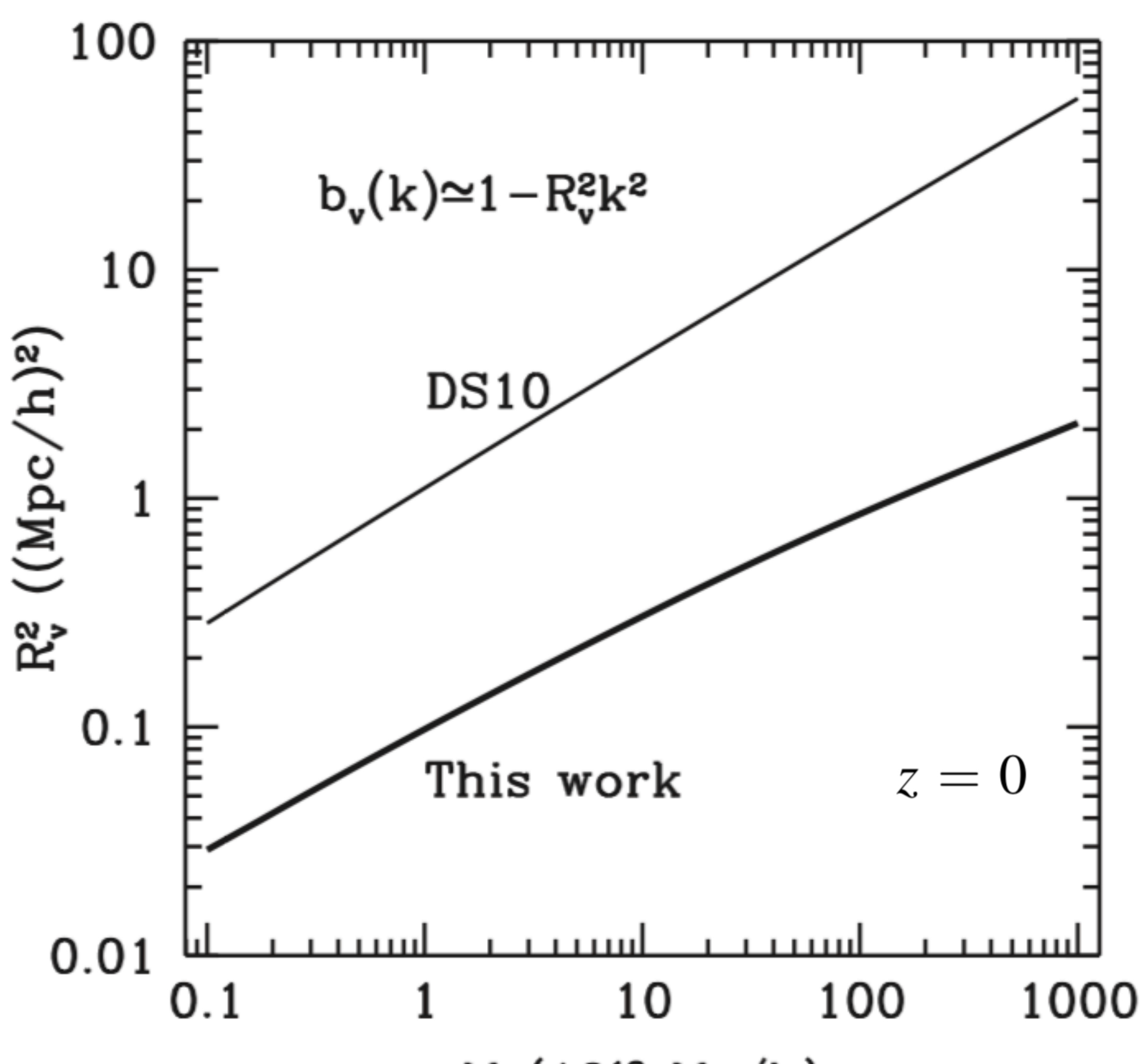
Gaussian Copula hypothesis

$$b_v(k) \simeq 1 - R_v^2 k^2,\ R_v^2 \equiv \frac{\sigma_G^2}{\sigma_{\nabla G}^2}$$

1. nonGaussian: Log-normal $G(\delta) = \ln(1+\delta) - \langle \ln(1+\delta) \rangle$

2. smoothing scale: spherical collapse $R_\Delta = (3M/(4\pi\Delta\bar{\rho}_m))^{1/3}$

3. nonlinearity: enhance small scale power



$$R_v^2 = \frac{(1+\sigma_\delta^2)\ln(1+\sigma_\delta^2)}{\sigma_{\nabla\delta}^2}.$$

$$\sigma_{\delta,\nabla\delta,v}^2 = \int \frac{k^3}{2\pi^2} P_\delta(k) W_{\rm TH}^2(kR_\Delta) k^{0,2,-2} \frac{dk}{k}.$$

Pengjie Zhang, 1811.07136

Not the end…, high order terms in RSD model?

$$P_h^{(\mathrm{S})}(k,\mu) = D^{\mathrm{FoG}}(k\mu\sigma_{z,h})P_{\mathrm{perturbed},h}(k,\mu)$$
$$= D^{\mathrm{FoG}}(k\mu\sigma_{z,h})[P_{\delta_h\delta_h} + 2\mu^2 P_{\delta_h\theta_h} + \mu^4 P_{\theta_h\theta_h}$$
$$+A_h(k,\mu) + B_h(k,\mu) + F_h(k,\mu) + T_h(k,\mu)]\,.$$

e.g.

$$B(k,\mu) = (k\mu f)^2 \int \frac{d^3\boldsymbol{p}}{(2\pi)^3} F(\boldsymbol{p})F(\boldsymbol{k}-\boldsymbol{p}),$$
$$F(\boldsymbol{p}) = \frac{p_z}{p^2}\left\{P_{\delta\Theta}(p) + f\,\frac{p_z^2}{p^2}\,P_{\Theta\Theta}(p)\right\}.$$

estimator — b_v effects

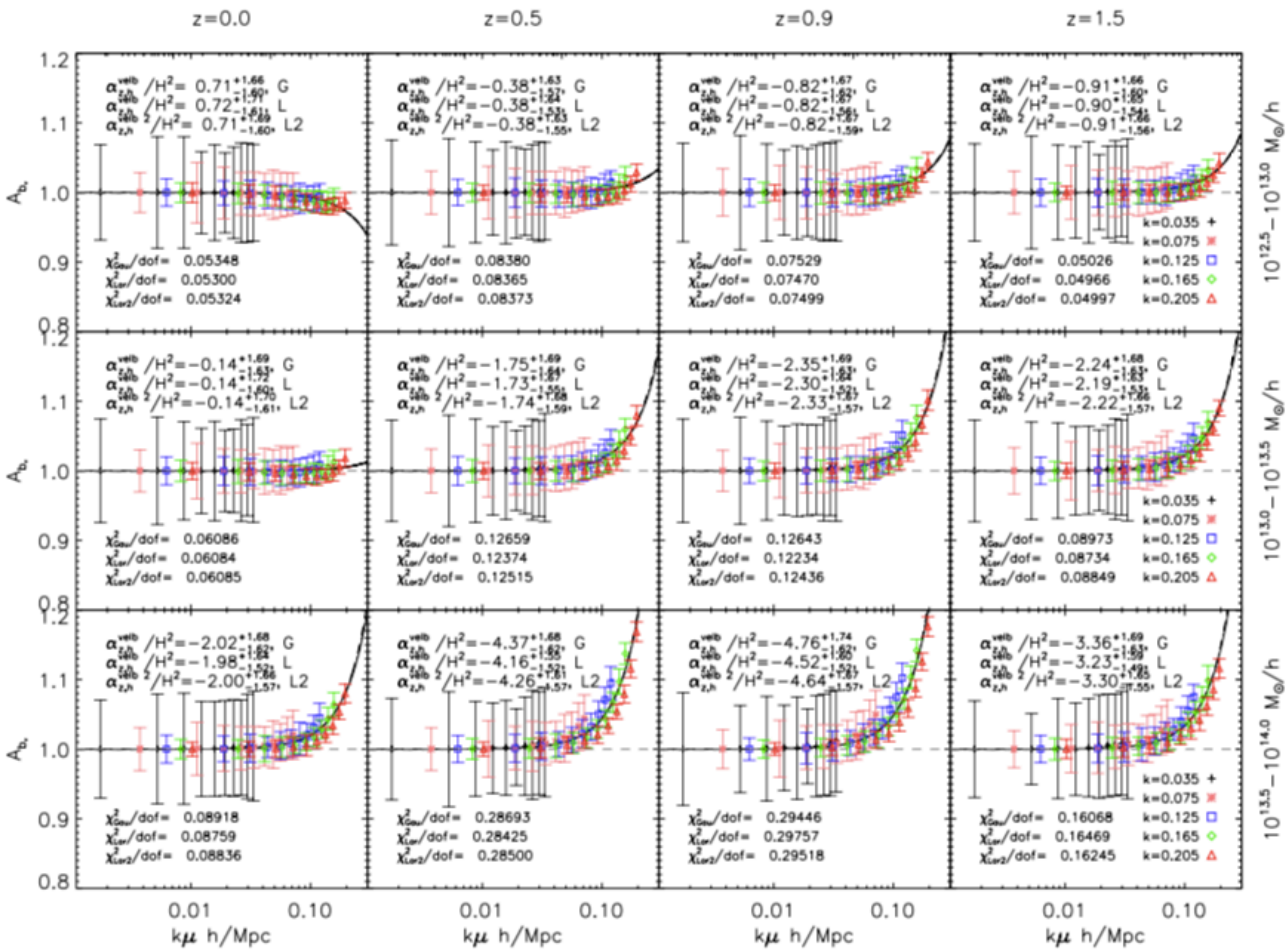
$$A_{b_v} \equiv \frac{P_h^{(\mathrm{S})}(k,\mu)}{P_{h,v_{DM}}^{(\mathrm{S})}(k,\mu)}\,, \quad (3.1)$$

in which

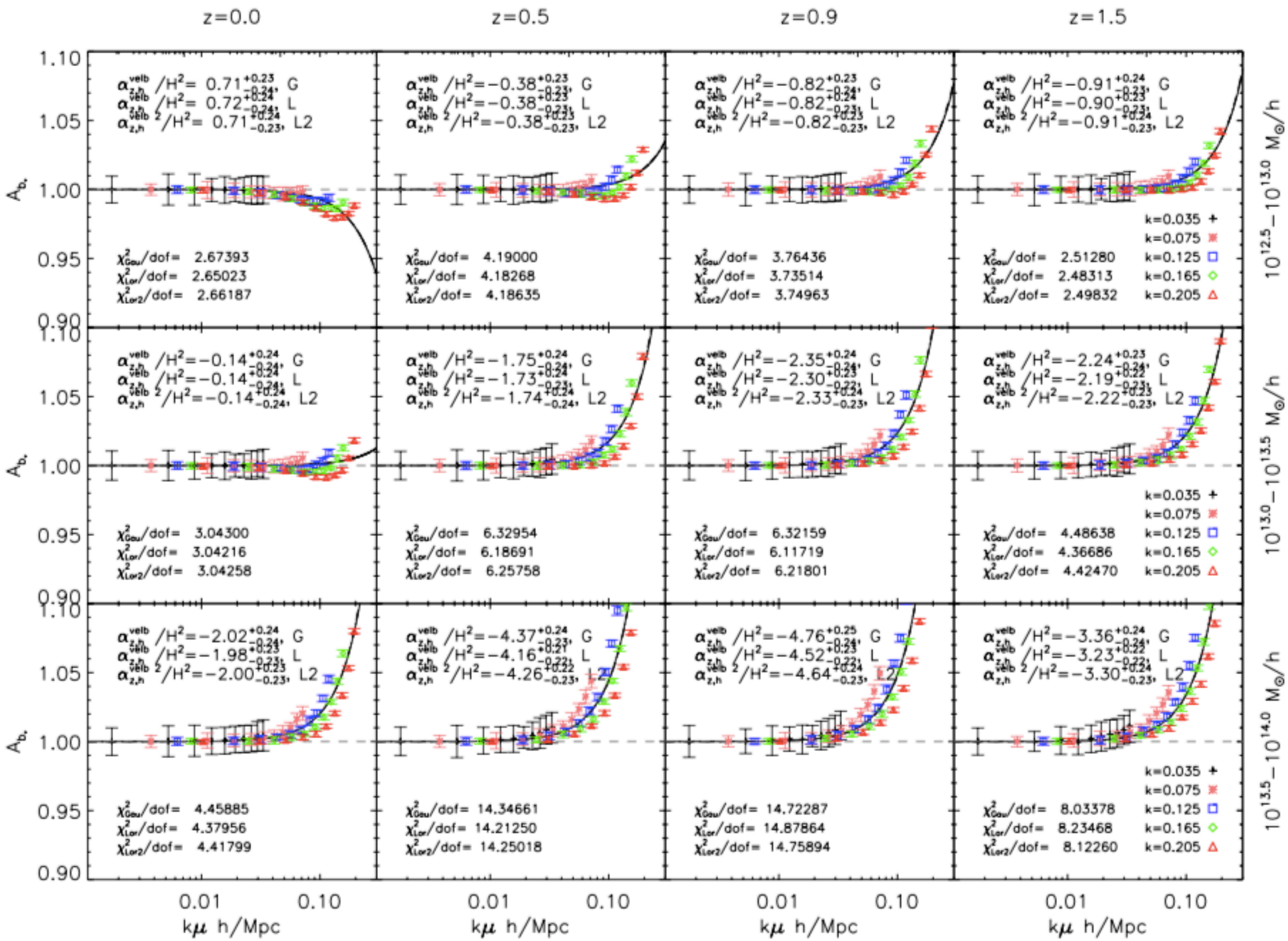
$$P_{h,v_{DM}}^{(\mathrm{S})}(k,\mu) \equiv \int d^3\boldsymbol{x}\, e^{i\boldsymbol{k}\cdot\boldsymbol{x}}\left\langle e^{j_1(u_z(\boldsymbol{r})-u_z(\boldsymbol{r}'))}(\delta_h(\boldsymbol{r}) + \nabla_z u_z(\boldsymbol{r}))(\delta_h(\boldsymbol{r}') + \nabla_z u_z(\boldsymbol{r}'))\right\rangle\,. \quad (3.2)$$

Zheng et al. 1807.08115

With 1 realization, 1.89(Gpc/h)^3



With 50 realizations:



Thanks!