Elucidating the impact of massive neutrinos on halo assembly bias

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Content

Background & Motivation

- Massive neutrinos → Lack of clustering on scales below free-streaming length → Scale-dependent growth of the LSS
- Neutrino condensation effect: differential growth of the dark matter haloes between environments of different neutrino-to-dark matter density ratios (Yu et al. 2017)

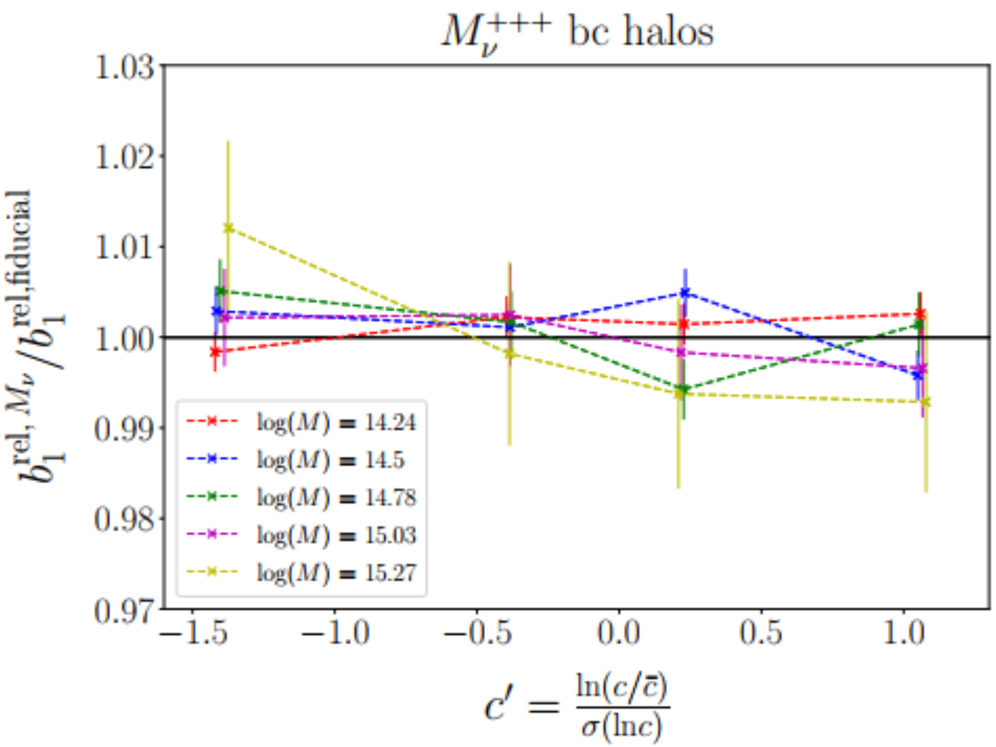
halo formation history → late time halo parameter (e.g. halo assembly bias)

- The Stage IV cosmological surveys: DESI, PFS, Roman, EUCLID, and CSST…

understand the impact of massive neutrinos on halo formation → **learn about massive neutrinos**

Background & Motivation

- No effect from massive neutrinos (Lazeyras et al. 2021)



- **Quijote: 0.0eV, 0.1eV, 0.2eV, 0.4eV**
- **neutrinos do no affect assembly bias of cluster sized halos for any of the property considered.**

A statistical analysis at the halo population level is not adequate for revealing the subtle but systematic effect of massive neutrinos, we need to watch for the evolution of the same initial density peaks with neutrinos on and off.

Our Work

- Method

Quijote: 0.0eV, 0.4eV (same initial condition)

abundance matching → **halo match** → **build twin halo catalog** → **compare halo properties**

- **abundance matching**: (same halo mass function)
- **halo match**: (trace by particles) (match the initial peaks)
- **build twin halo catalog**: (compute useful parameters)

✓ Eliminate systematic differences from cosmology

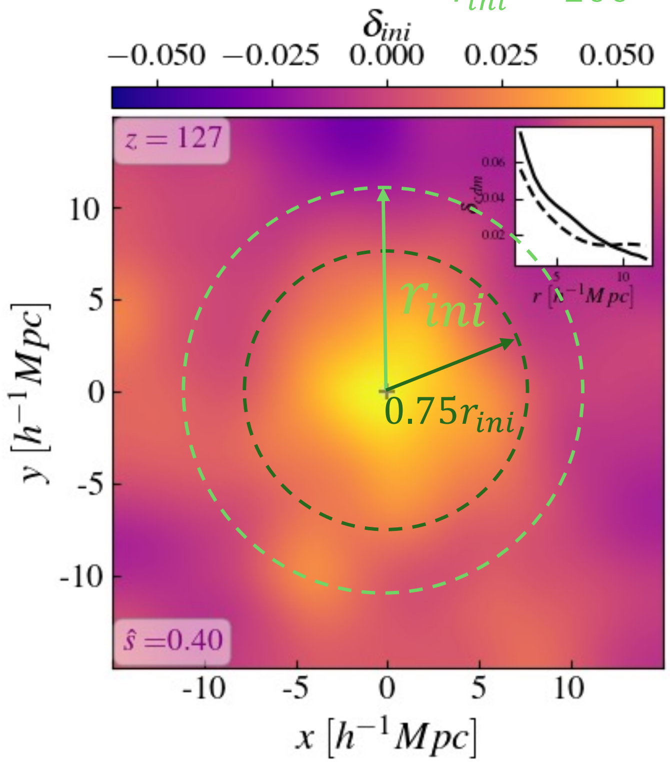
✓ Clear the data

✓ Find the halos' structure differences

Our Work

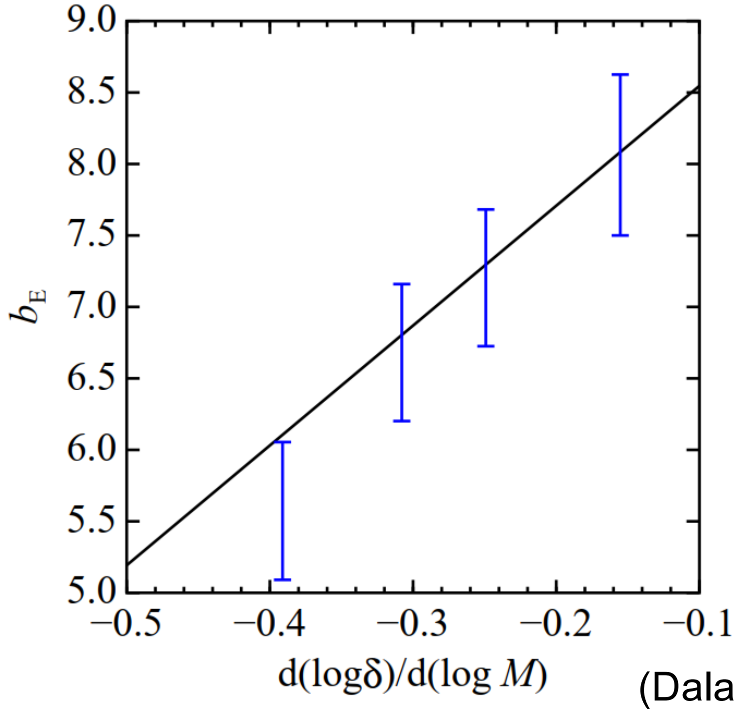
- Definition of peak curvature $\hat{s}$

$r_{ini} = 200^{1/3} r_{200m}$

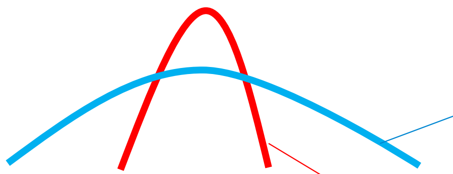


$$s = -\frac{\Delta \delta_{cdm}}{\Delta \log M_{inside}}$$

$$\hat{s} = s - \langle s \mid M_h \rangle$$



(Dalal 2008)



shallow curvature, neg $\hat{s}$, high bias

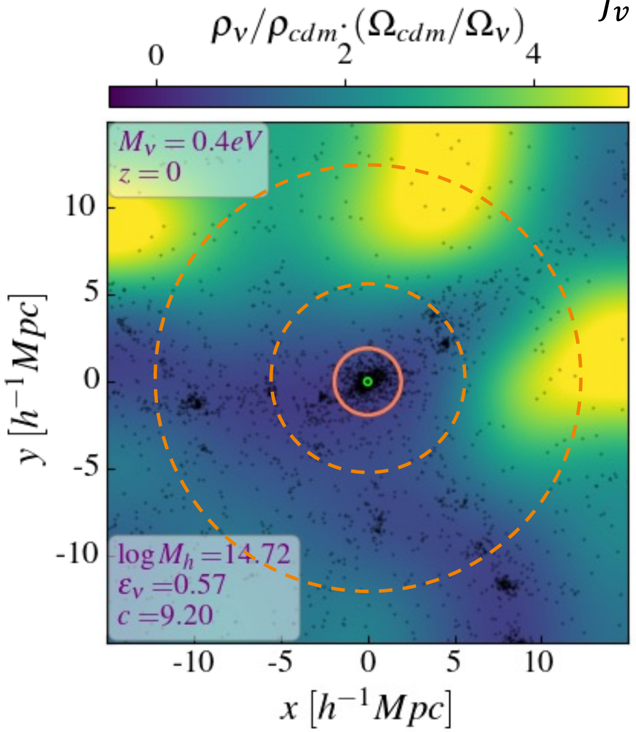
steep curvature, pos $\hat{s}$, low bias

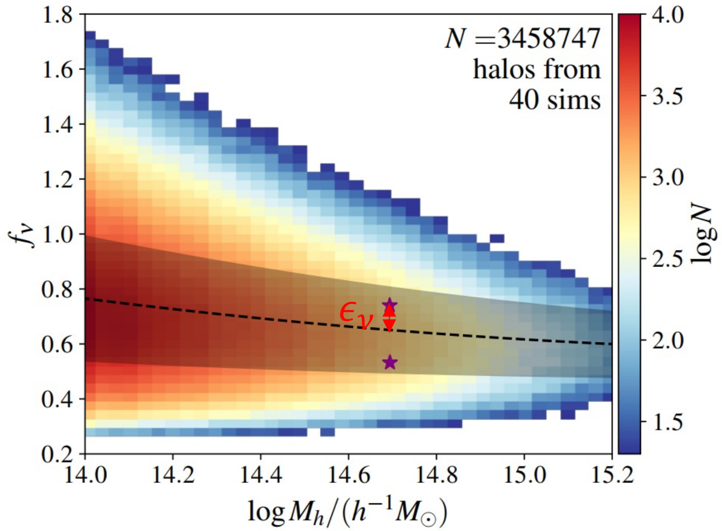
Our Work

- Definition of neutrino excess ϵ_ν

$$f_\nu \equiv \frac{\Omega_{\rm cdm}}{\Omega_\nu} \cdot \left[\frac{\rho_\nu(r)}{\rho_{\rm cdm}(r)}\right]_{\rm r=5-12Mpc/\mathit{h}}$$

- **pos ϵ_ν → neutrino rich**
- **neg ϵ_ν → neutrino poor**





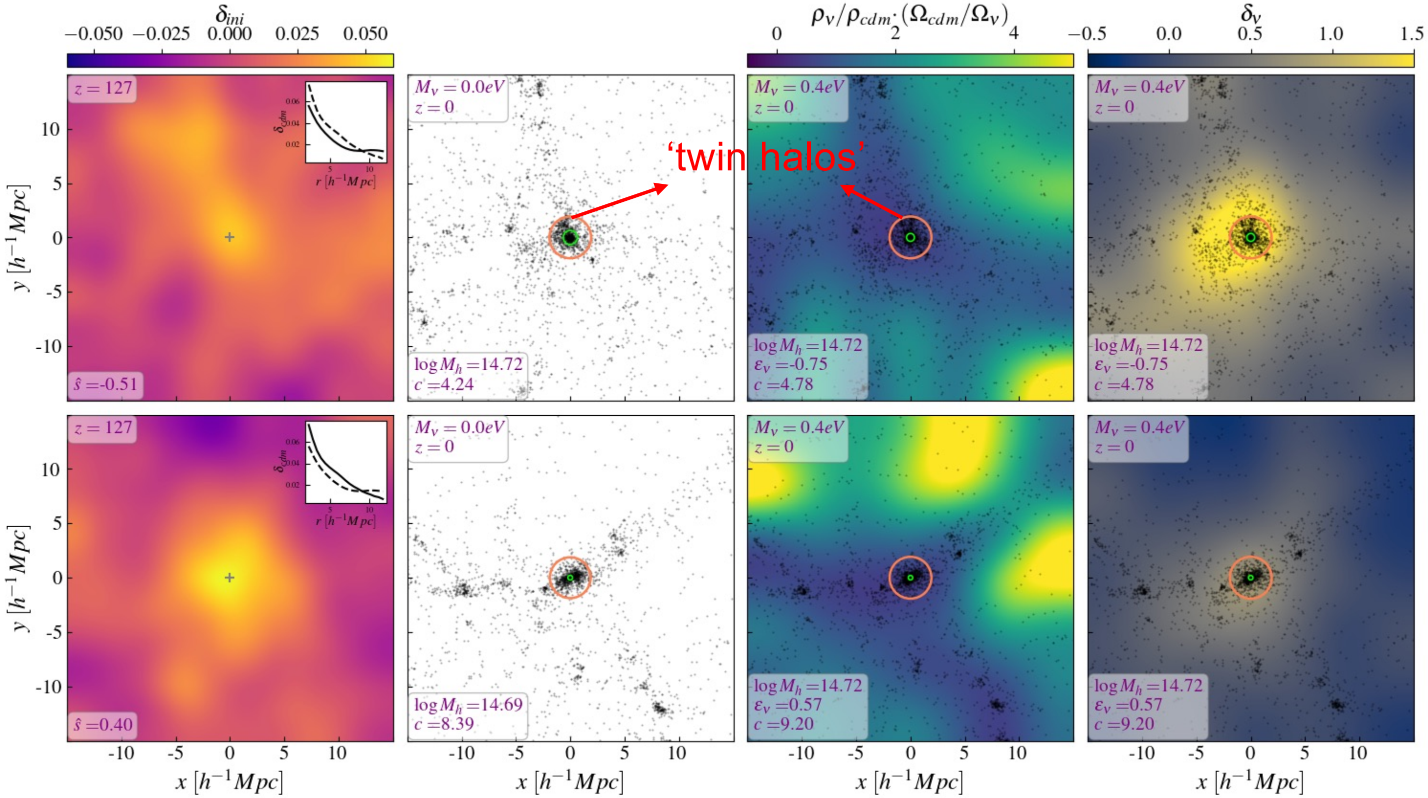
$$\epsilon_\nu \equiv \frac{f_\nu - \langle f_\nu \mid M_h\rangle}{\sigma_{f_\nu}(M_h)}$$

Our Work

- Twin-halo catalog

shallow curvature

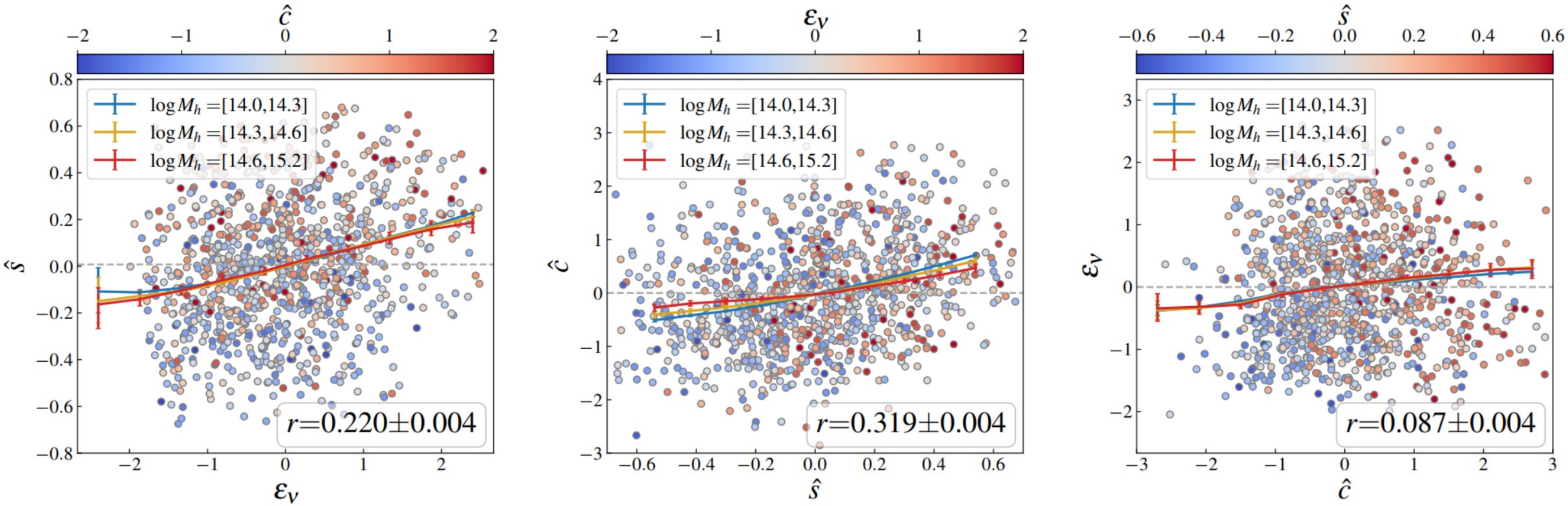
steep curvature



Our Work

- ϵ_ν $vs.\hat{s}$ $vs.\hat{c}$

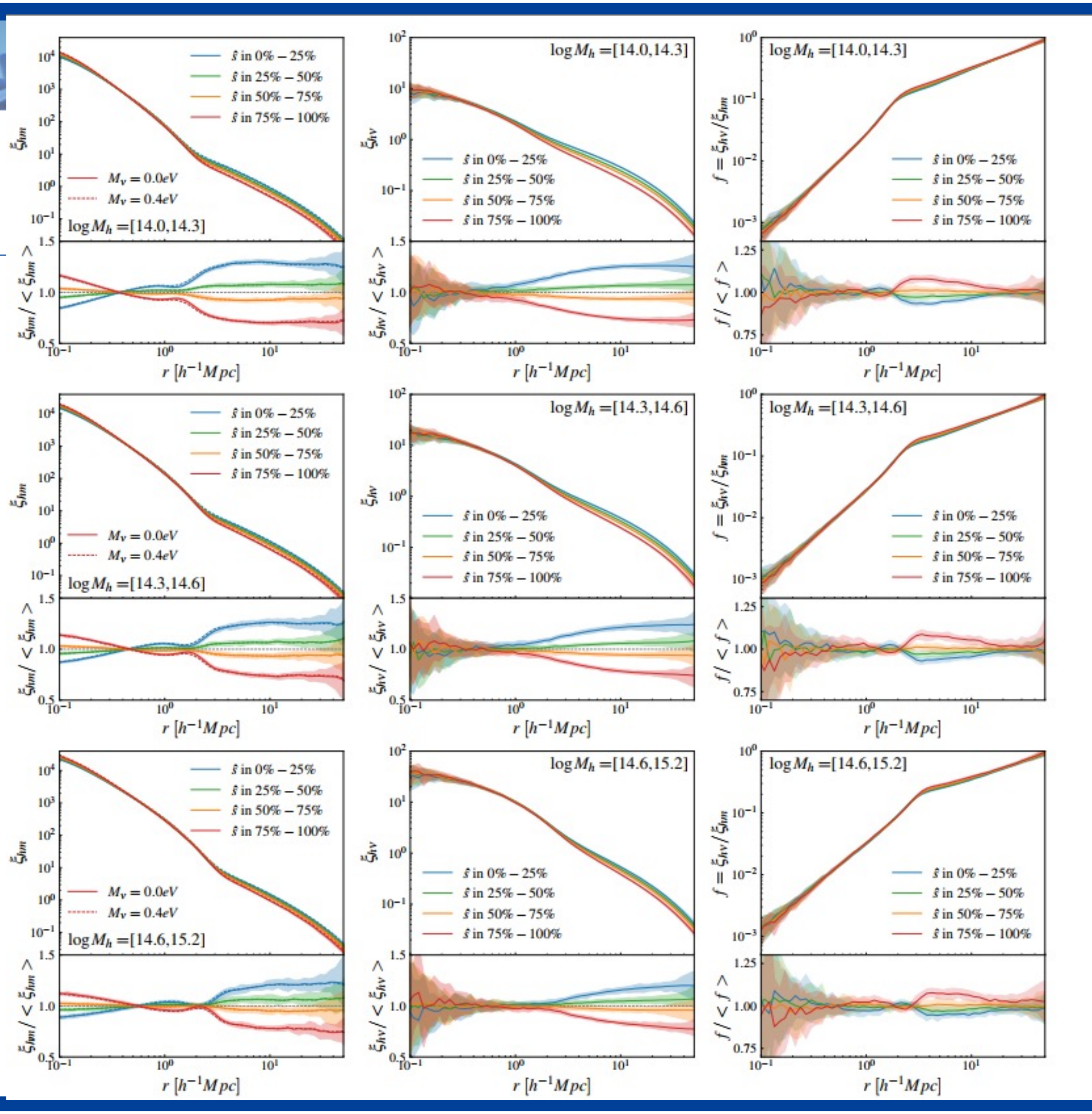
$$\hat{c} = \frac{c - < c(M_h) >}{\sigma_c(M_h)}$$



- **Steep initial peak curvature → neutrino rich**
- **Steep initial peak curvature → large concentration**
- **High concentration, neutrino rich (weak correlation)**

Our Work

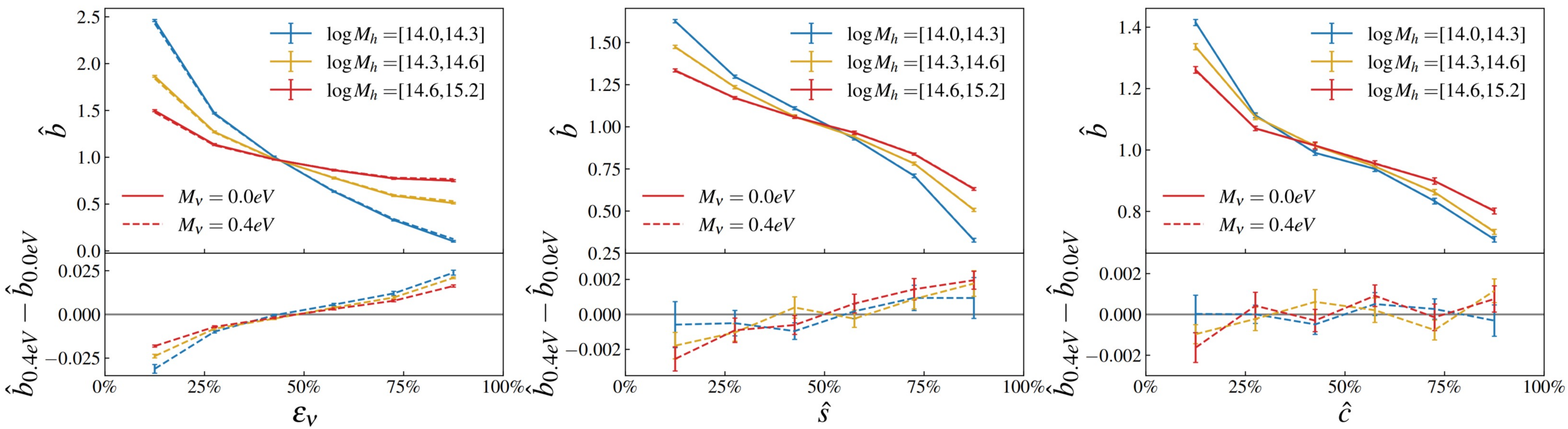
- $\hat{s} \rightarrow \xi_{hm}, \xi_{hv}, \xi_{hm}/\xi_{hv}$
- **No obvious difference for ξ_{hm} between $0.0eV$ and $0.4eV$ simulation**
- **ξ_{hv} and ξ_{hm} show similar trend with the change of curvature.**
- **Compared to CDMs' concentration and bias, neutrinos' are less influenced by curvature.**



Our Work

- $\hat{c}, \epsilon_\nu, \hat{s} \rightarrow$ halo assembly bias

$$b = \frac{\xi_{hm}}{\xi_{mm}}, \qquad \hat{b} = \frac{b}{\langle b \mid M_h \rangle}$$



- **Massive neutrino impact on ‘bias dependency on various signals’**
- **Clear difference for $\hat{b} - \epsilon_\nu$, $\hat{b} - \hat{s}$ between massive and massless neutrino simulations**
- **The difference for $\hat{b} - \hat{c}$ can hardly be found.**

Summary

- We conduct one-to-one halo matching to build 'twin halo catalog', one with massive neutrinos and one without massive neutrinos.
- Haloes grow up from steep initial curvature are more possible to live in neutrino-rich environment and have larger concentration at late time.
- We do find the massive neutrino impact on halo assembly bias, though the effect is quite weak.