Accelerating Universe in the Dark - 2019.3.6 - Kyoto

Effect of astrophysics on the large-scale clustering of HI

arXiv:1808.01116

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Contents

RSD of HI gas with hydrodynamic simulations
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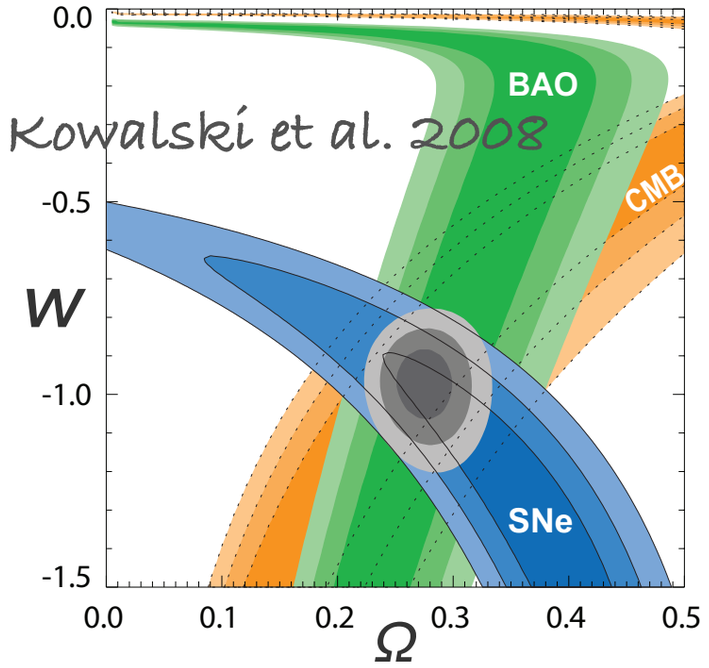
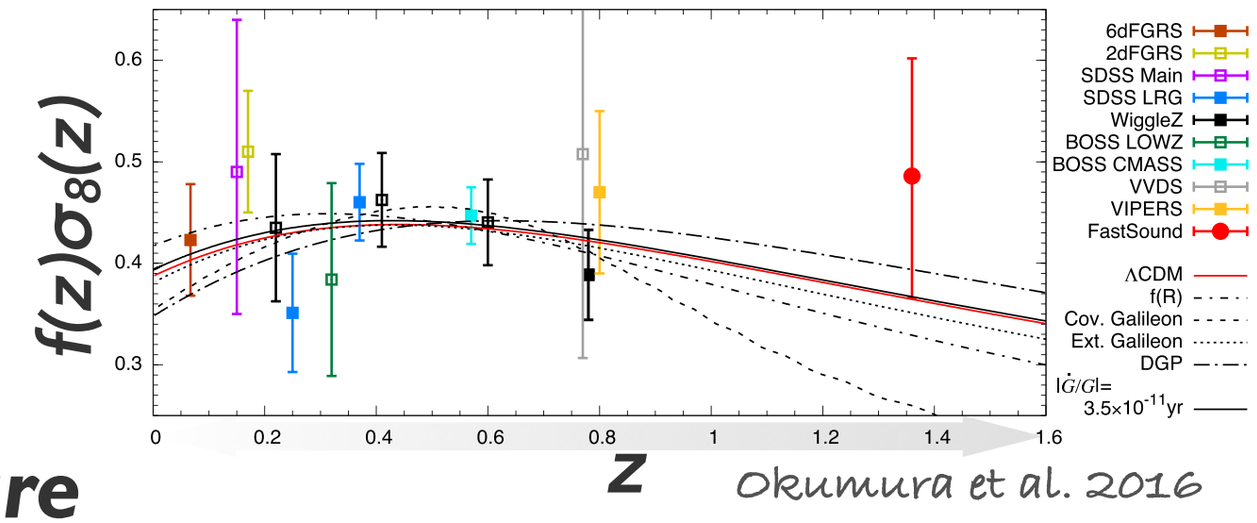
accelerating expansion and LSS

origin of accelerating expansion

(dark energy or modified gravity)

- expansion history
- growth rate





probe of large-scale structure

→ power spectrum, correlation function, BAO, RSD …

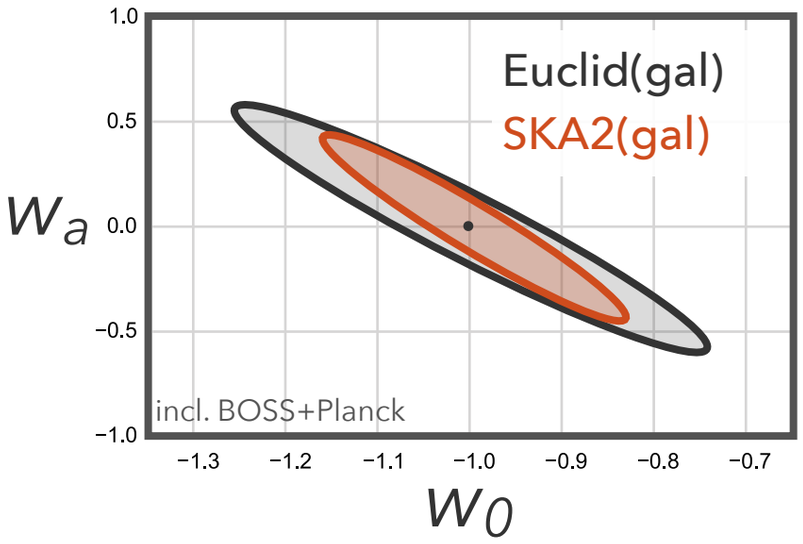
Neutral hydrogen as a new tracer of dark matter

21cm line intensity mapping

- wide area
- wide range of redshift

previous study Bull et al. 2015

forecast the constraint on the cosmological parameter by SKA



strong constraint on the dark energy is expected by 21cm line intensity mapping

EoS of DE $p_{\rm de} = w\,\rho_{\rm de}$

$w = w_0 + (1-a)\,w_a$

previous study and this work

previous study Sarkar et al. 2016, 2018

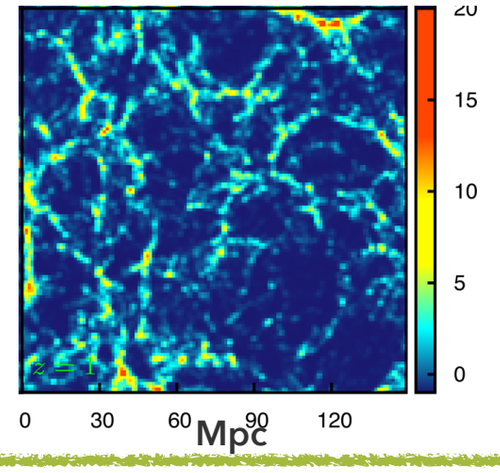
semi-numerical simulation to model the HI distribution

N-body simulation

gravitational interaction of dark matter

assume M_{halo}-M_{HI} relation

HI density map



- modeling HI bias
- measure RSD of HI

depend on model of M_{halo}-M_{HI} relation

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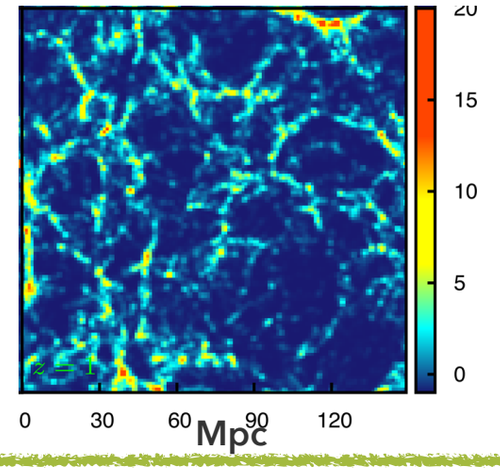


- modeling HI bias
- measure RSD of HI

depend on model of M_{halo}-M_{HI} relation

this work

using cosmological hydrodynamic simulation

→ ***construct theoretical model based more on reality***

two cosmological hydrodynamic simulations

investigate the impact of the uncertainties about small-scale astrophysics on the large-scale clustering of HI

including different small-scale astrophysics
(e.g. Star formation, SNe and AGN feedback)

Illustris simulation

moving mesh code AREPO

Box size : $(75\ \mathrm{cMpc/h})^3$

Particle number : $2*455^3$

Strong AGN feedback

Osaka simulation

N-body/SPH code Gadget-3 (Springel 2005)

Box size : $(85\ \mathrm{cMpc/h})^3$

Particle number : $2*512^3$

No AGN feedback

particle mass [M_{sun}/h] DM : ~$6*10^7$, baryon : ~$3*10^8$

Vogelsberger et al. (2014), Nelson et al. (2015) Aoyama et al. 2017, Shimizu et al. 2019

this work: HI bias

RSD of HI gas with hydrodynamic simulations
arXiv:1808.01116

1. Introduction

- galaxy survey
- 21cm line intensity mapping

2. HI bias

- BAO peak scale
- scale dependence

3. Redshift space distortion of HI

- theoretical model
- measure using simulation data

4. Summary

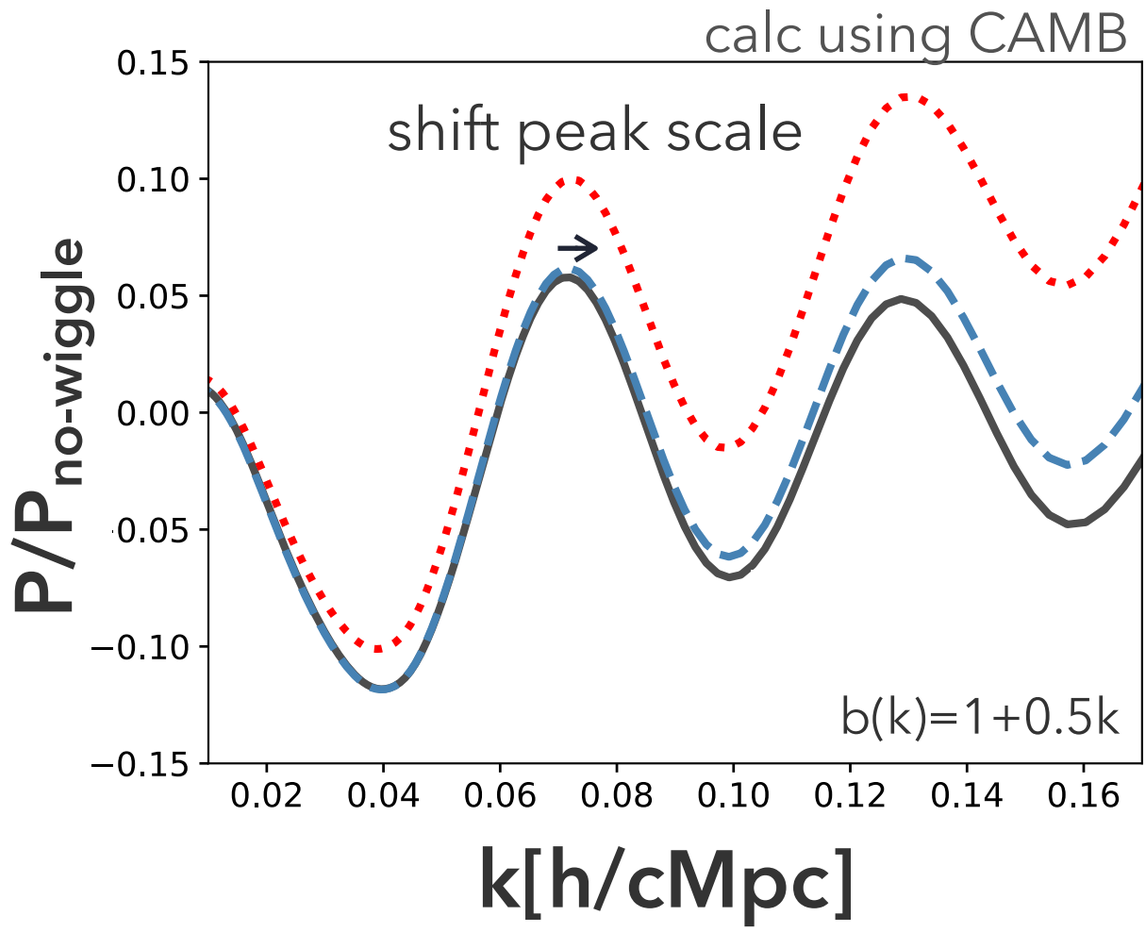
bias b(k) affect the BAO peak scale

measured BAO peak scale deviates from

the BAO scale of dark matter predicted by linear theory

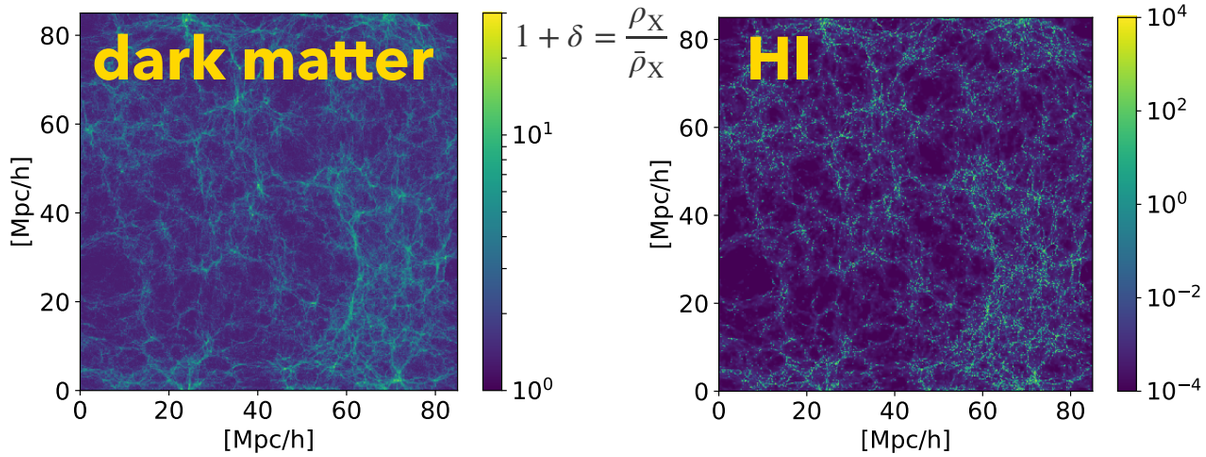
- ***non-linear effect***
- ***scale dependent bias***

$$\delta_{HI} = b_{HI}(k)\,\delta_m$$



scale & redshift dependence of HI bias

21cm line is a biased tracer of matter distribution



measure and model the HI bias in real space

at 1<z<5 using the two simulations

$$b(k) = \frac{P_{\rm HI-m}}{P_{\rm m}}$$

HI bias

HI-matter cross-correlation

matter auto-correlation

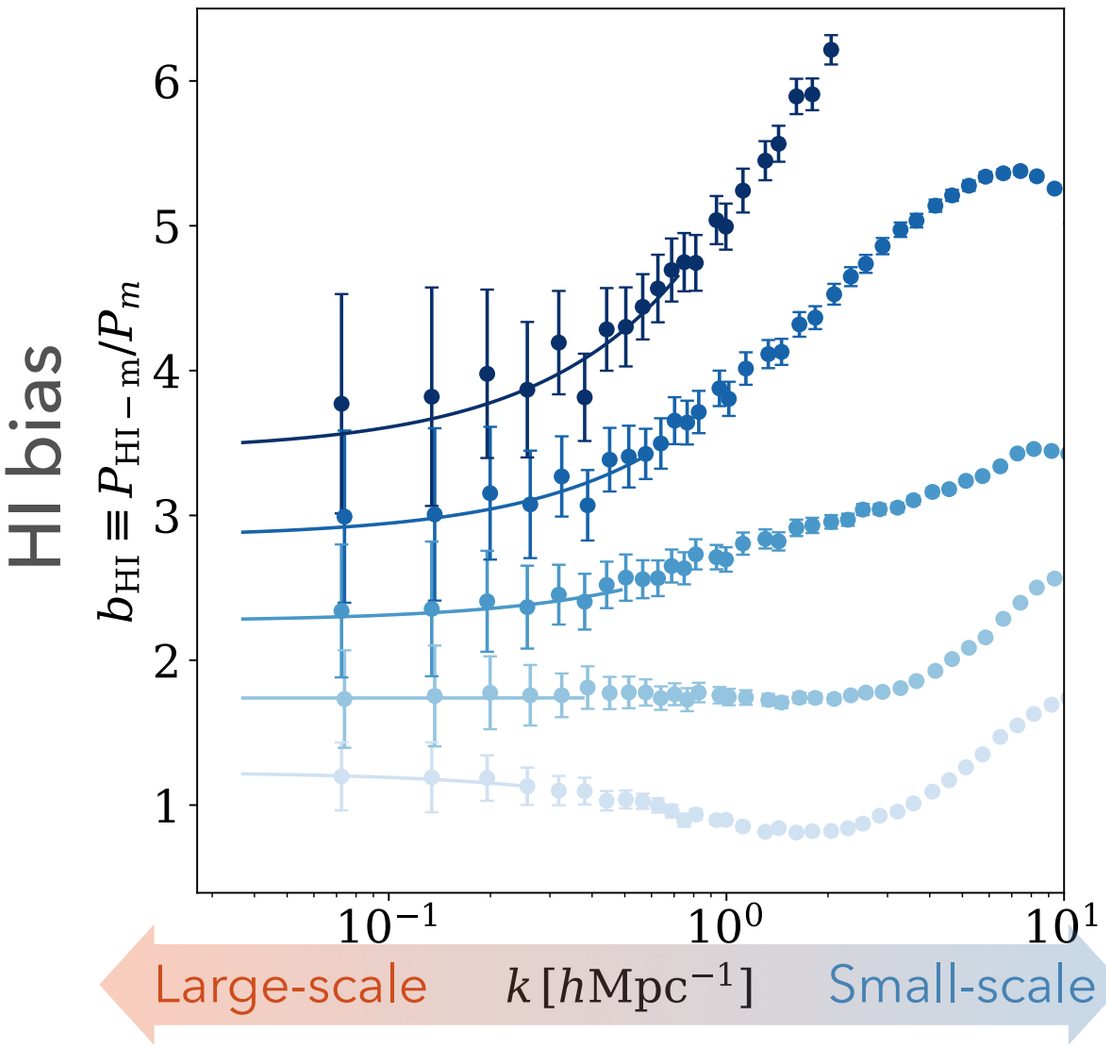
result: HI bias

$$b(k) = \frac{P_{\mathrm{HI-m}}}{P_{\mathrm{m}}}$$

symbol: simulation data

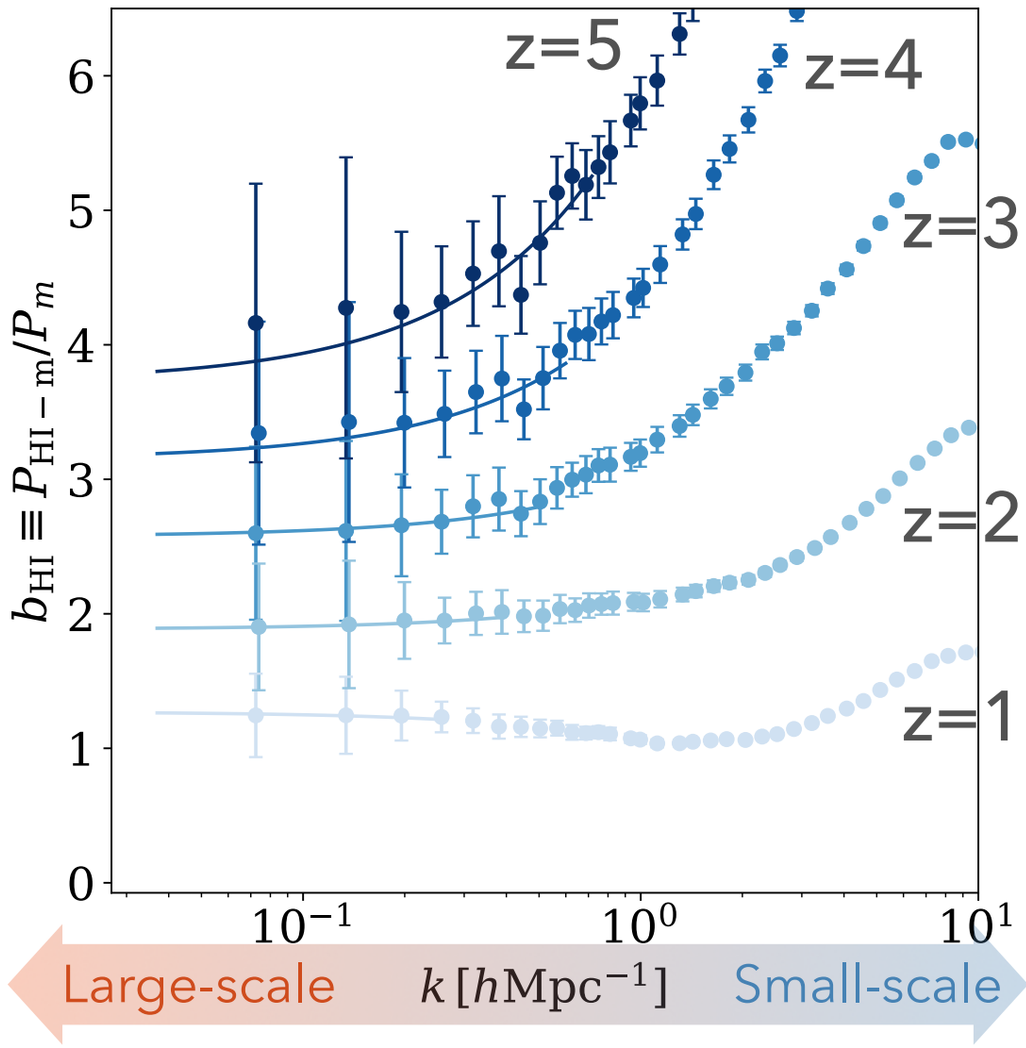
curve: b_0+b_1k

Illustris (w/ AGN)



wave length

Osaka (w/o AGN)



wave length

$$\frac{k_{\mathrm{max}}^2}{6\pi^2}\int_0^{k_{\mathrm{max}}} dk\, P^{\mathrm{lin}}(k,z) = C \sim 0.7$$

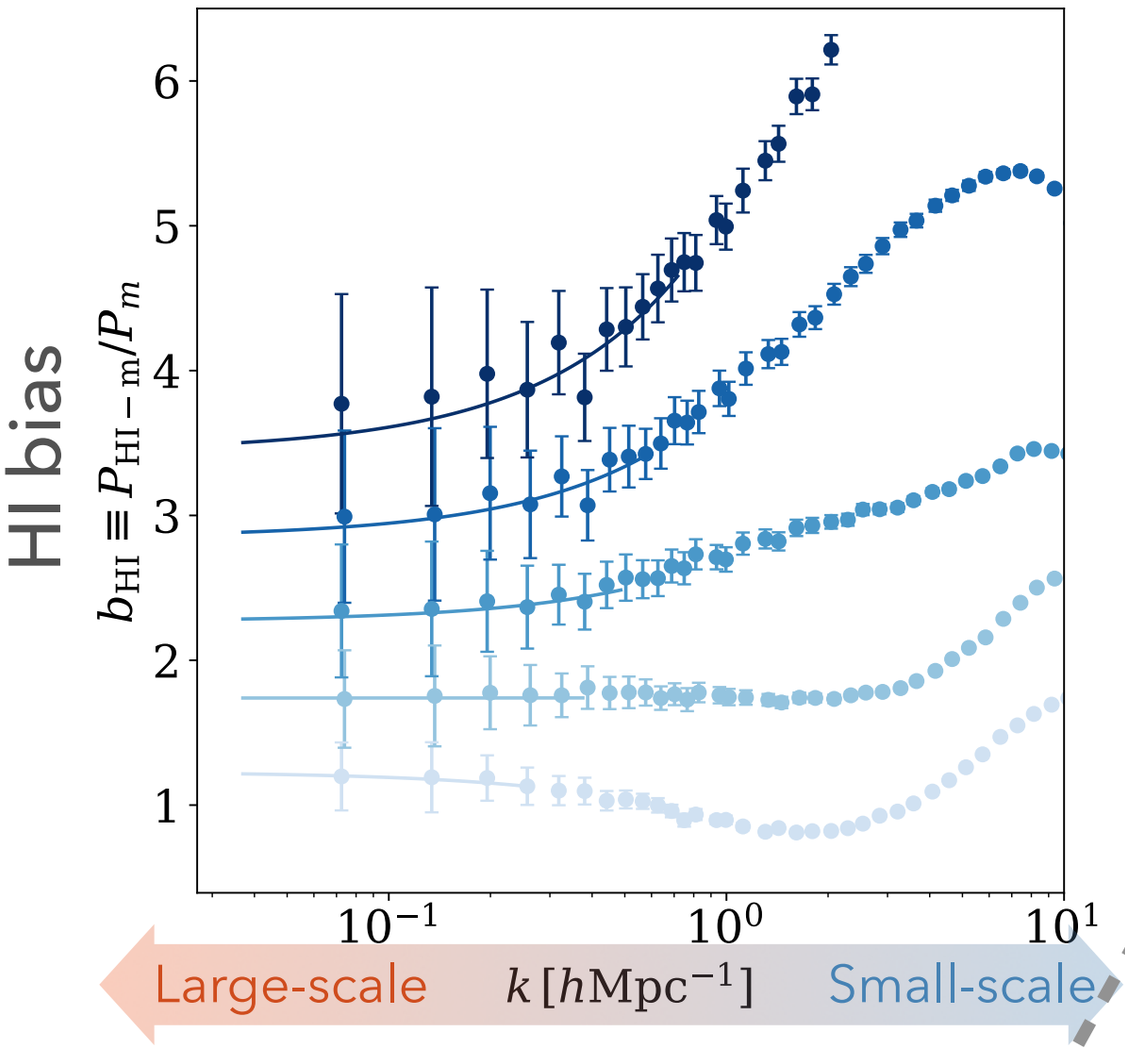
result: HI bias

$$b(k) = \frac{P_{\mathrm{HI-m}}}{P_{\mathrm{m}}}$$

symbol: simulation data

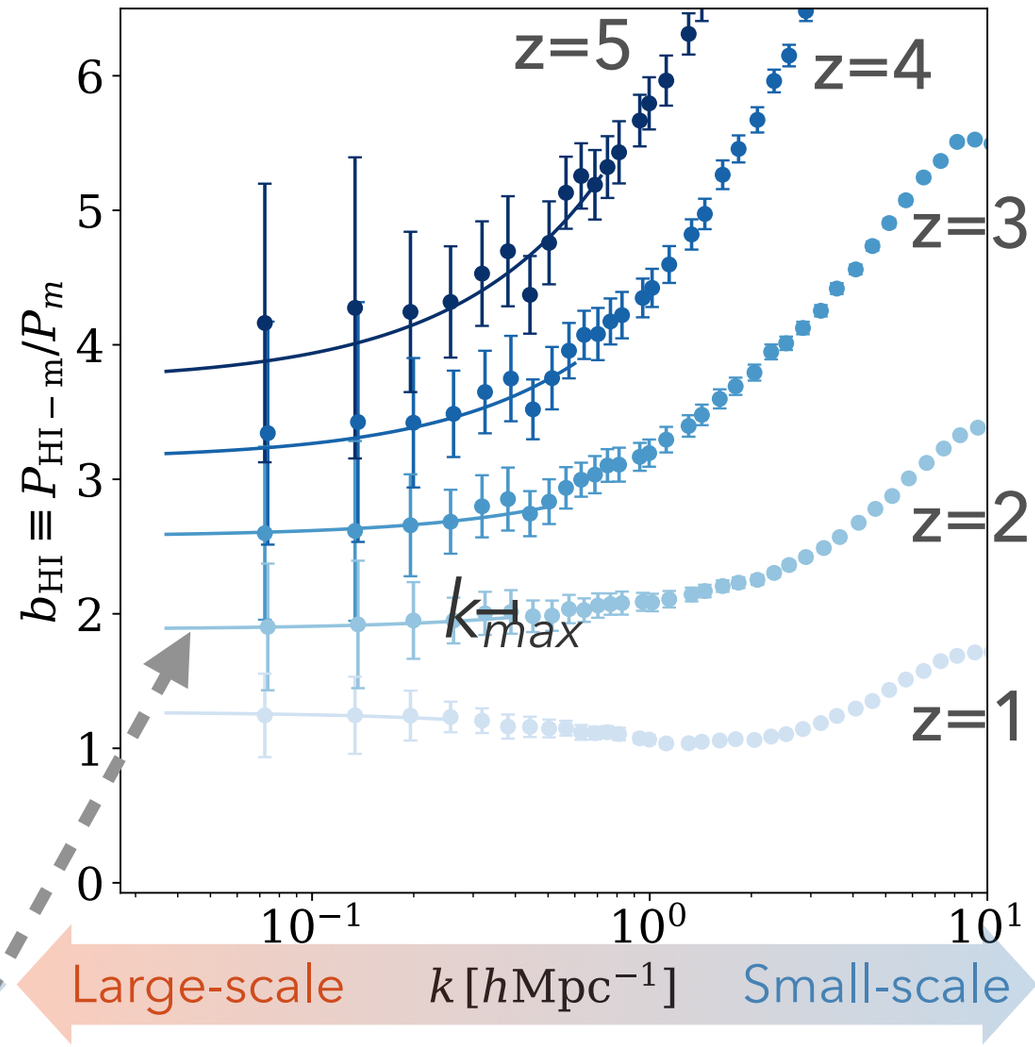
curve: b_0+b_1k

Illustris (w/ AGN)



wave length

Osaka (w/o AGN)



wave length

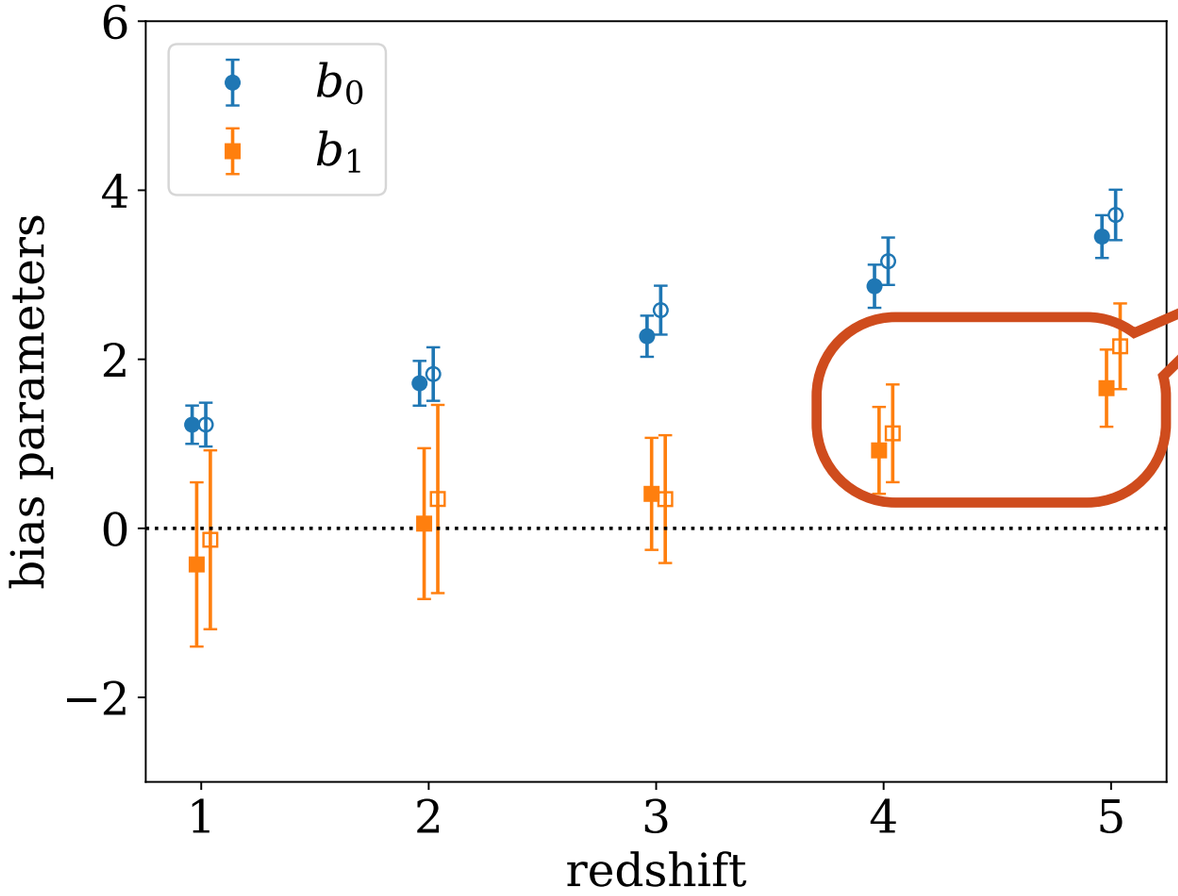
$$b(k) = b_0 + b_1 k$$

scale dependence

$$\frac{k_{\mathrm{max}}^2}{6\pi^2}\int_0^{k_{\mathrm{max}}} dk\, P^{\mathrm{lin}}(k,z) = C \sim 0.7$$

scale dependence & astrophysical effect

$b(k) = b_0 + b_1 k$



- filled: Illustris (w/ AGN)
- ○ open: Osaka (w/o AGN)

We find

- ***the scale dependence of HI bias at z > 3***

  (e.g. k<0.5 h/Mpc @ z=3)

- ***weak effect of the small-scale astrophysics on large-scale HI bias***

  (e.g.star formation, SNe, AGN)

this work: Redshift space distortion

RSD of HI gas with hydrodynamic simulations

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4. Summary

construct the RSD model for HI

Peculiar velocity affects only the distance along the line of sight

$$(s_1, s_2, s_3) = \left(x_1, x_2, x_3 + \frac{v_3}{aH}\right)$$

position in redshift space

position in real space

effect of the peculiar velocity

BUT

We have no theoretical model for RSD of HI

→ ***Exploring a RSD model applicable to HI***

theoretical model of RSD

$\mu = k_{\parallel}/k = \cos\theta$

$\beta = f/b_{\rm HI}$

f : 線形成長率

anisotropic power spectrum in redshift space

$$P_{\rm HI}(k,\mu) = e^{-(k\mu f\sigma_v)^2}\, b_{\rm HI}^2(1+\beta\mu^2)^2\, P_{\rm m}(k)$$

HI in redshift space

Finger of God suppress

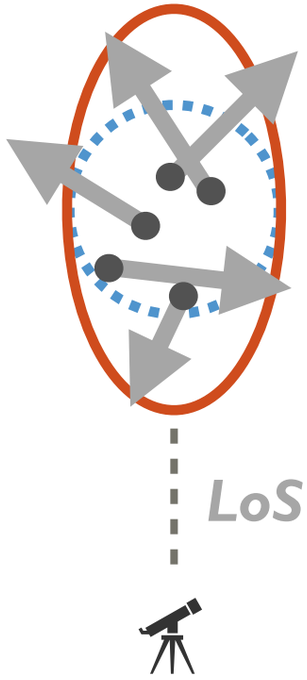
Kaiser enhance

matter in real space

Finger of God

small scales

Jackson et al. 1972

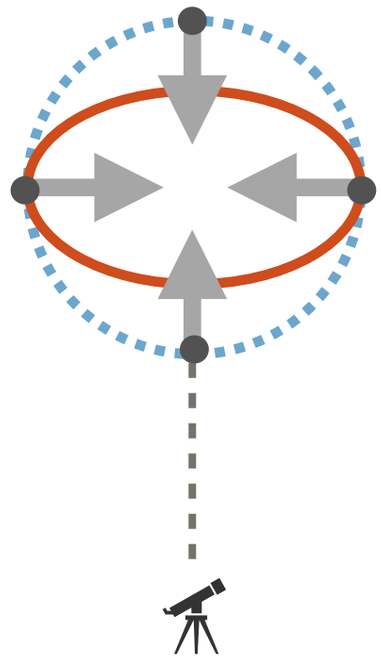


non-linear random motion

Kaiser

large scales

Kaiser et al .1987



coherent inflow towards overdense

peculiar velocity

real space

redshift space

multiple power spectra simulation vs model

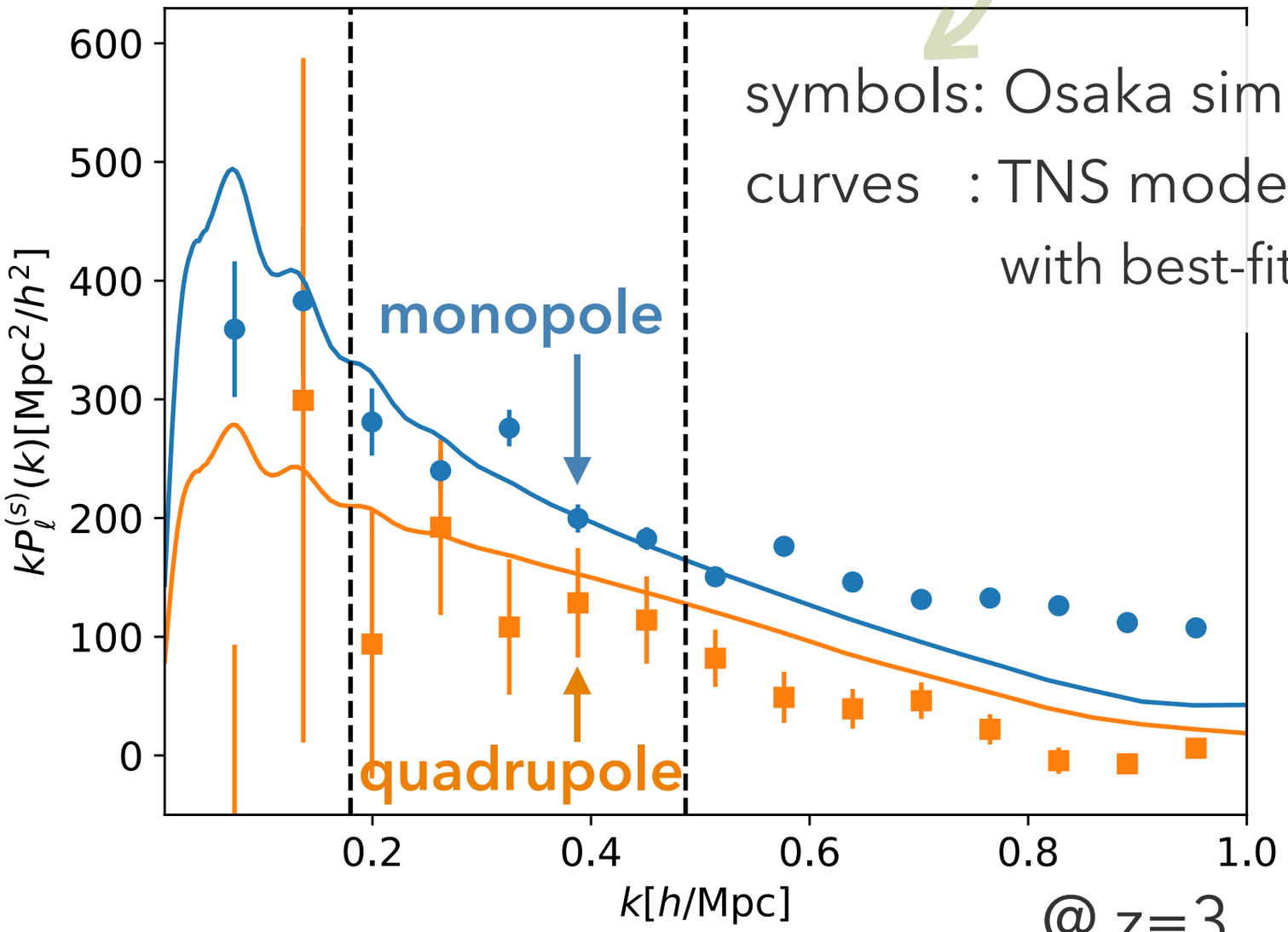
free parameters

model: $P_{\rm HI}(k,\mu) = W^2_{\rm beam}(k,\mu)\, e^{-(k\mu f \sigma_v)^2}\, b^2_{\rm HI}(1+\frac{f}{b_{\rm HI}}\mu^2)^2\, P_{\rm m}(k)$

+ TNS correction term

Taruya et al. 2010

$kP_l^{(s)}(k)$ ***Legendre expansion***



symbols: Osaka simulation

curves : TNS model with best-fitted parameters

@ z=3

$\frac{k^2_{\rm max}}{6\pi^2}\int_0^{k_{\rm max}} dk\, P^{\rm lin}(k,z) = C \sim 0.7$

multiple power spectra simulation vs model

free parameters

model: $P_{\rm HI}(k,\mu) = W^2_{\rm beam}(k,\mu)\, e^{-(k\mu f \sigma_v)^2}\, b^2_{\rm HI}(1+\frac{f}{b_{\rm HI}}\mu^2)^2\, P_{\rm m}(k)$

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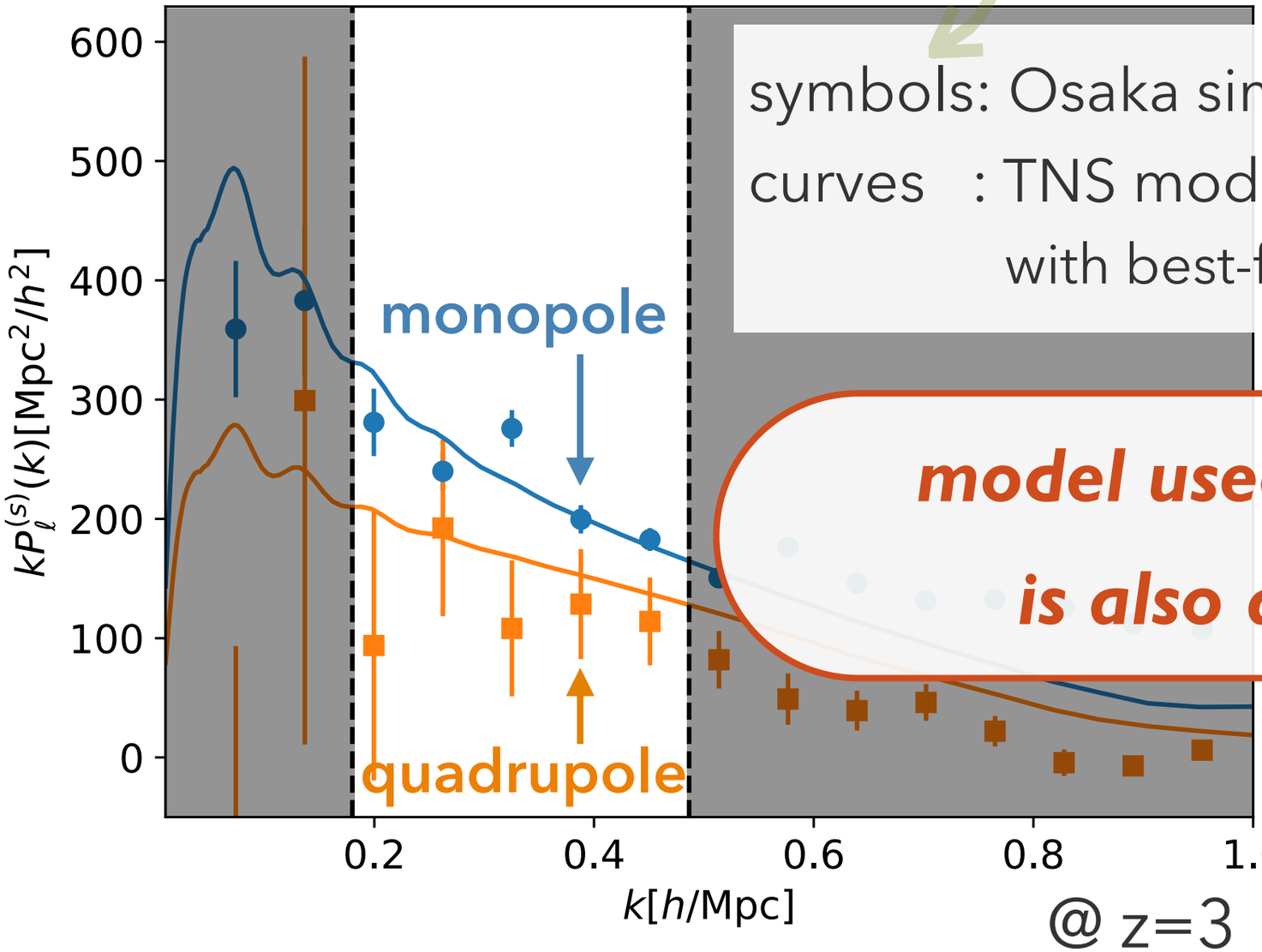

symbols: Osaka simulation

curves : TNS model with best-fitted parameters

model used for galaxy survey is also applicable to HI

@ z=3

$\frac{k^2_{\rm max}}{6\pi^2}\int_0^{k_{\rm max}} dk\, P^{\rm lin}(k,z) = C \sim 0.7$

best-fitted value: HI bias

constant

$$P_{\rm HI}(k,\mu) = W^2_{\rm beam}(k,\mu)\, e^{-(k\mu f\sigma_v)^2}\, b^2_{\rm HI}(1+\frac{f}{b_{\rm HI}}\mu^2)^2\, P_{\rm m}(k)$$

+ TNS correction term

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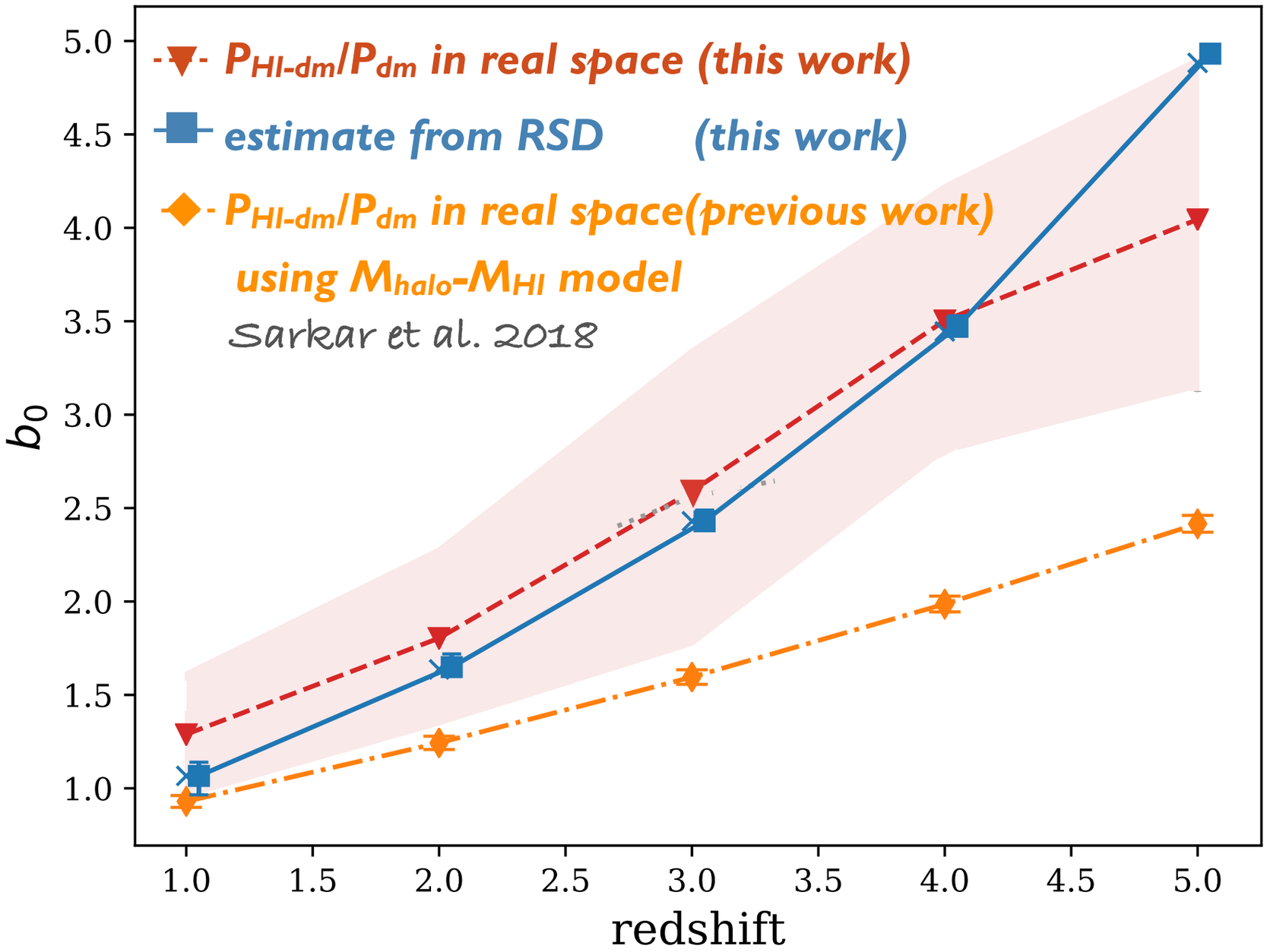

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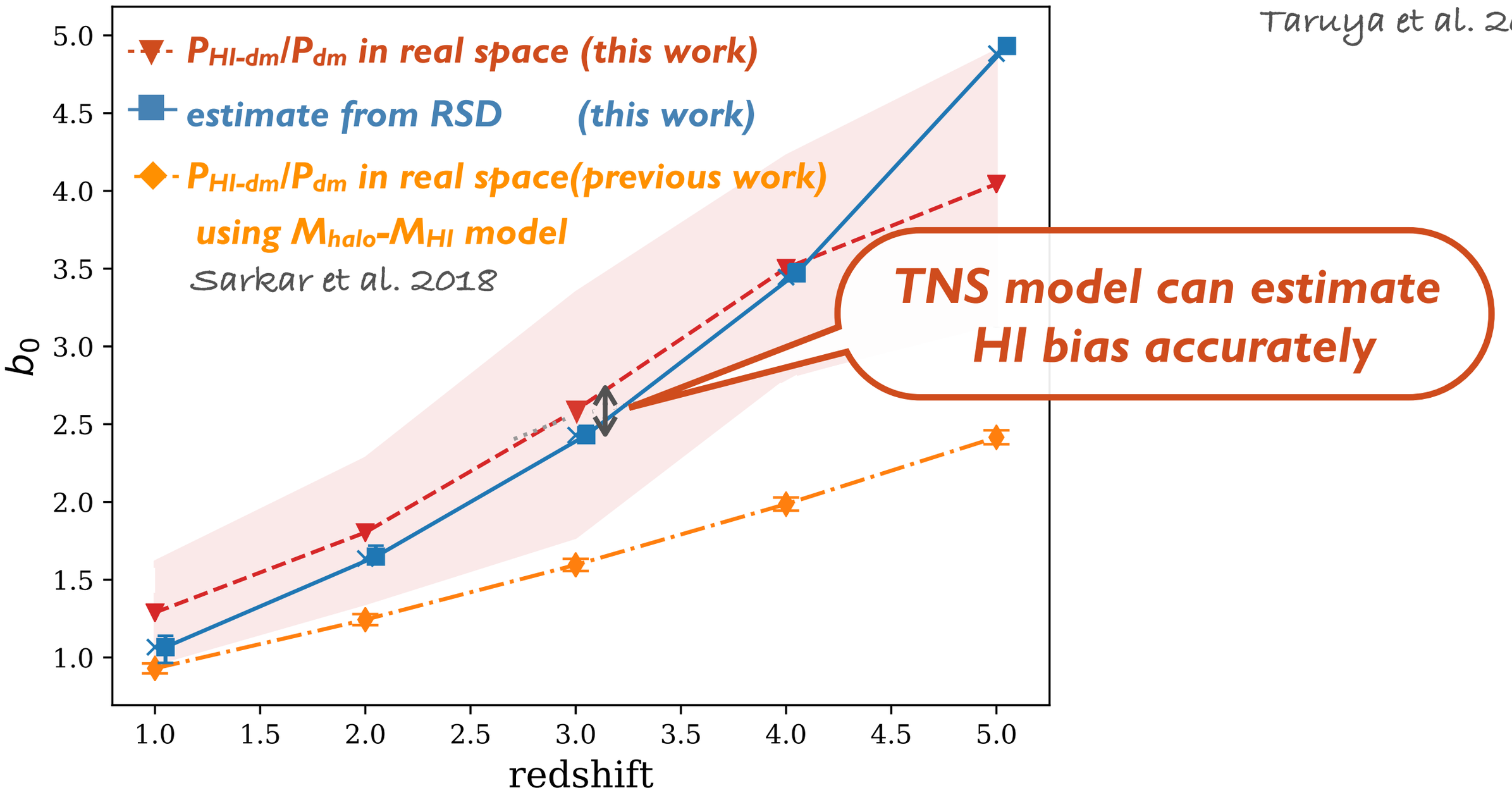

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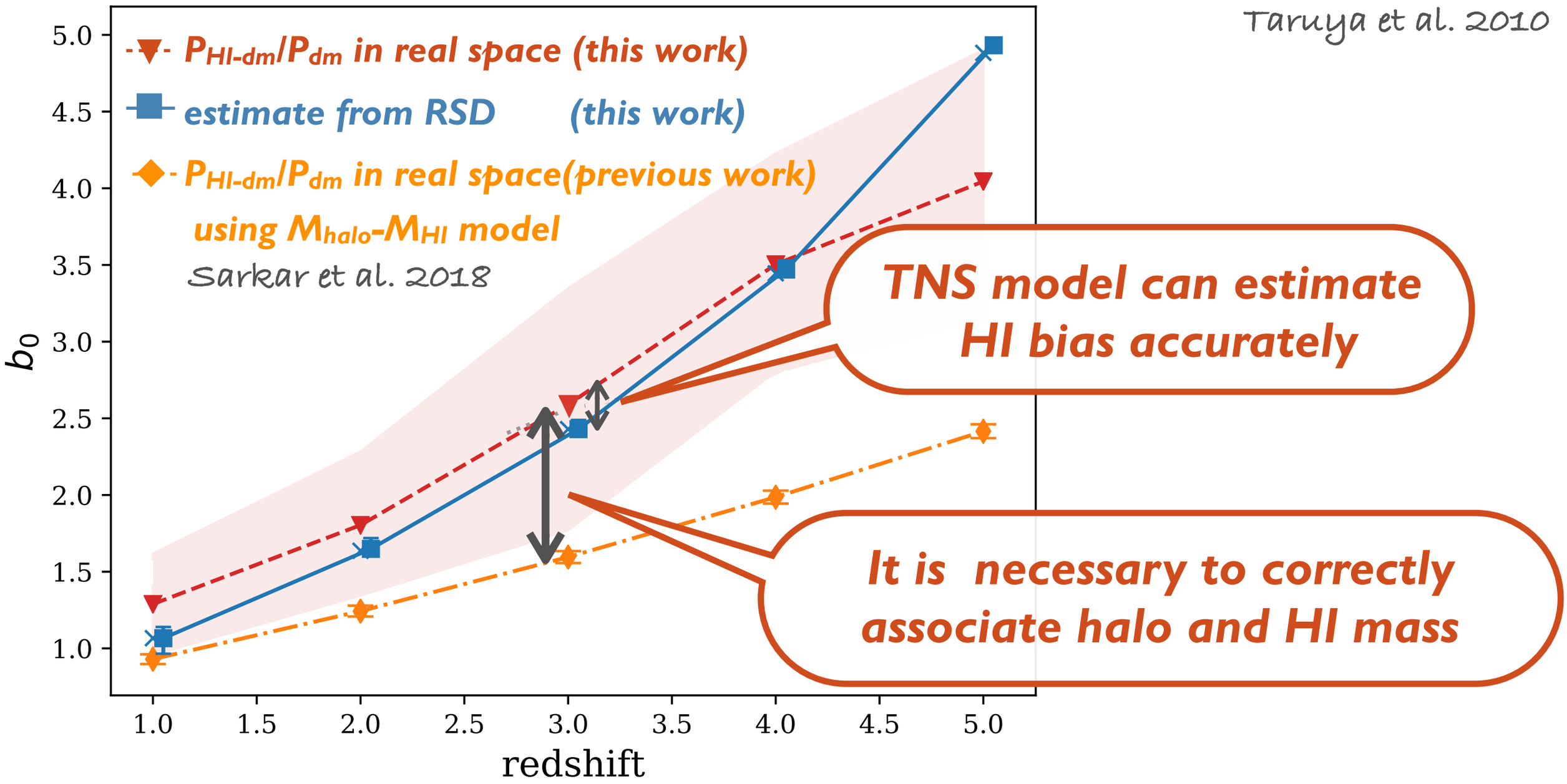

summary

aim: construct theoretical model for HI clustering

method: measure HI bias & RSD of HI

using two cosmological hydrodynamic simulations

result: direct measurement of HI bias in real space

- scale dependence (at z>3)
- weak effect of uncertainty about small-scale astrophysics

e.g. star formation, SNe, AGN feedback

result: redshift space distortion of HI

- theoretical model (TNS) for galaxy survey could be applied to HI
- investigation of relationship between halo and HI mass is necessary