Preliminary results of

Intrinsic alignment from the subhalo distribution

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BAO and RSD features are imprinted in the GI correlations

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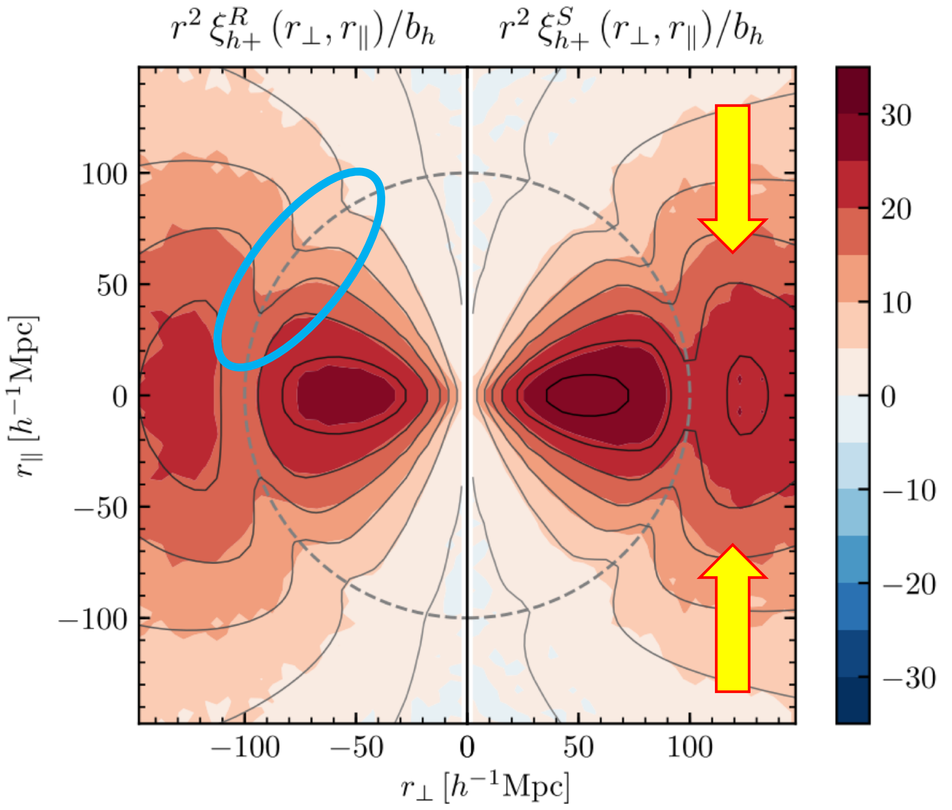
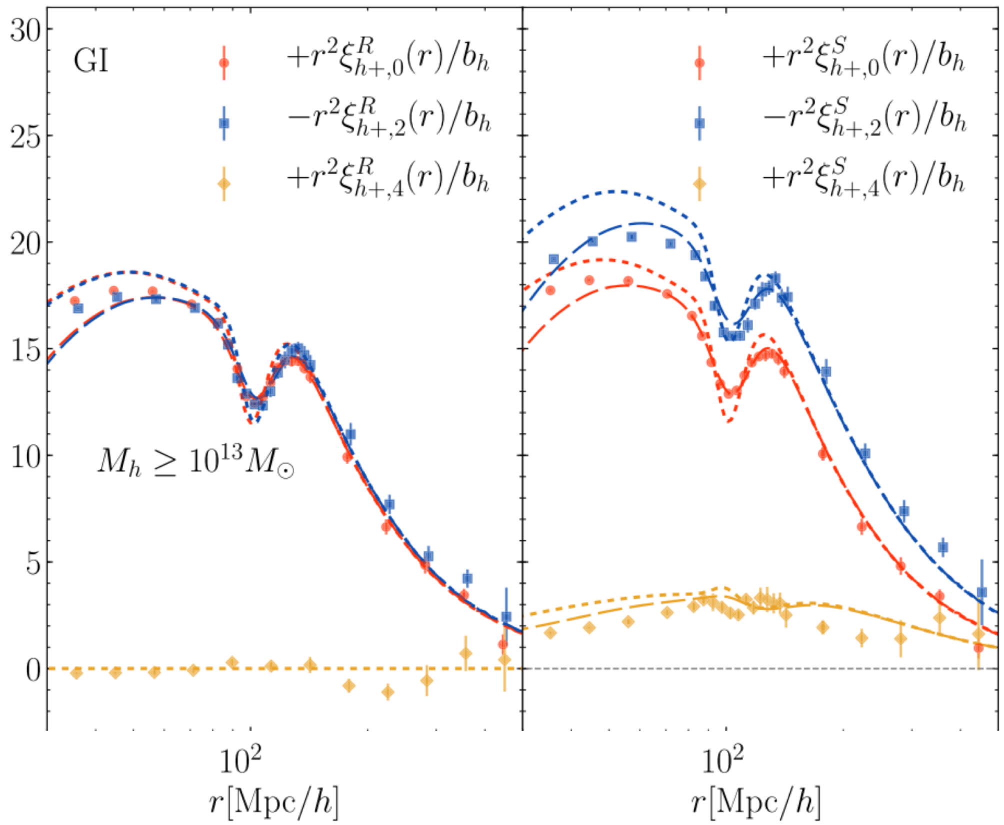
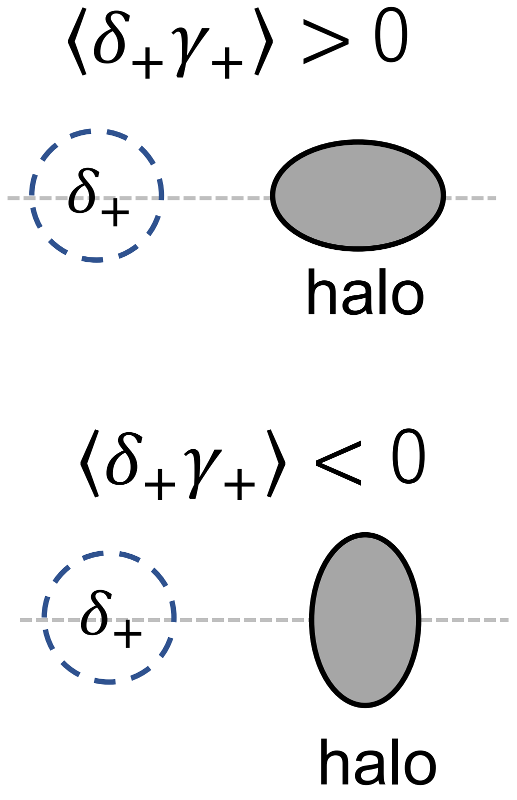


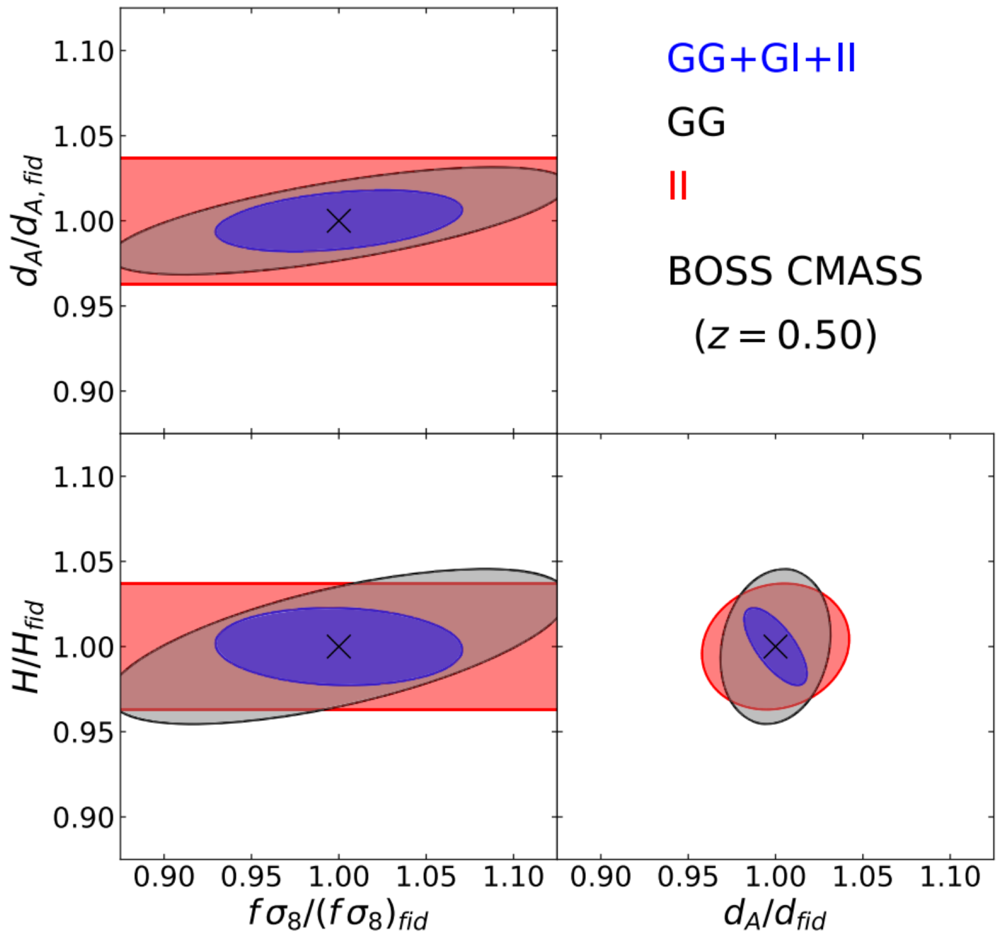




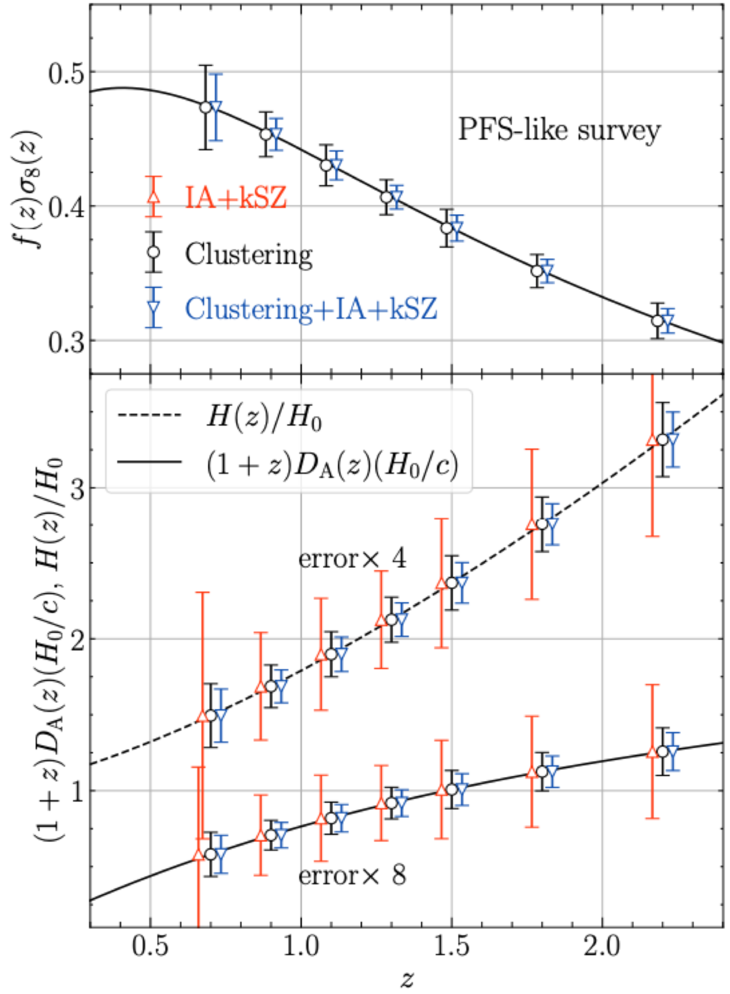
Okumura, Taruya, & Nishimichi (2020)

Galaxy density – Intrinsic ellipticity (GI) correlation

Cosmological parameters can be constrained by the GI correlations



Taruya & Okumura (2020)



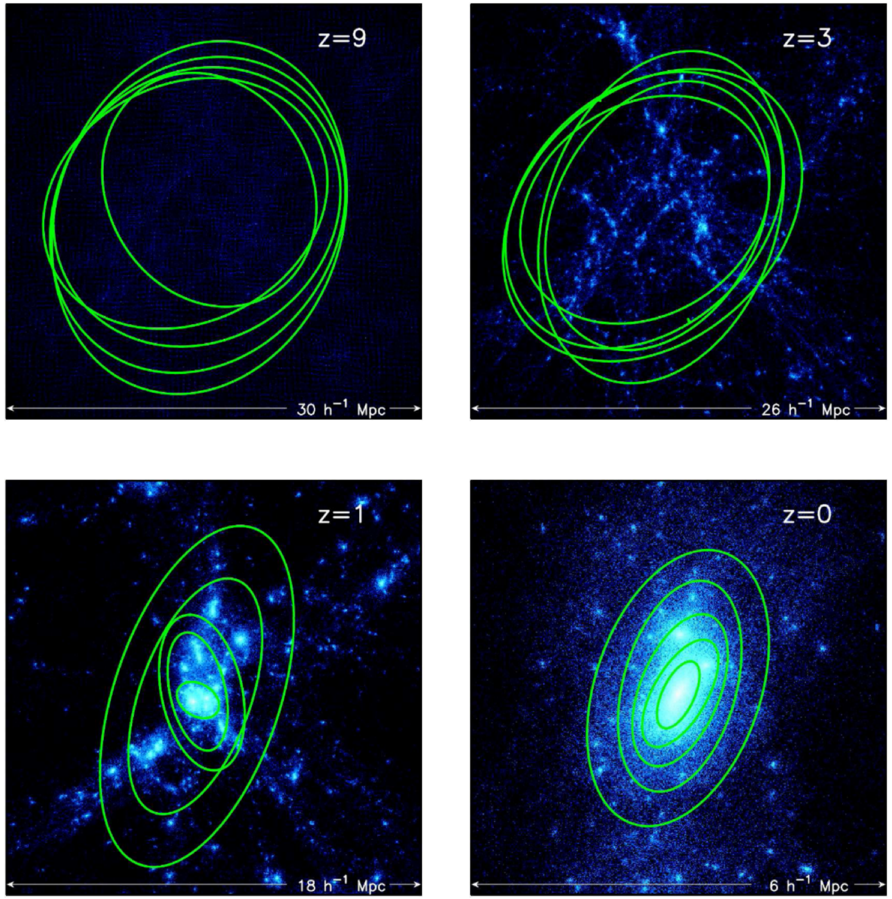
Okumura & Taruya (2022)

Galaxy clustering + IA statistics improve constraints on geometry and dynamics

Strong constraints require high-quality IA correlation measurements

Galaxy density – Intrinsic ellipticity (GI) correlation

Halo IAs in simulations…



Suto et al. (2016)

Halo shapes and IA statistics are well studied using the distribution of dark matter particles

Impossible to represent this situation by observation

Shapes from DM particles x density field from DM particles

… very accurate results, but impossible

Shapes from satellites x density field from galaxies

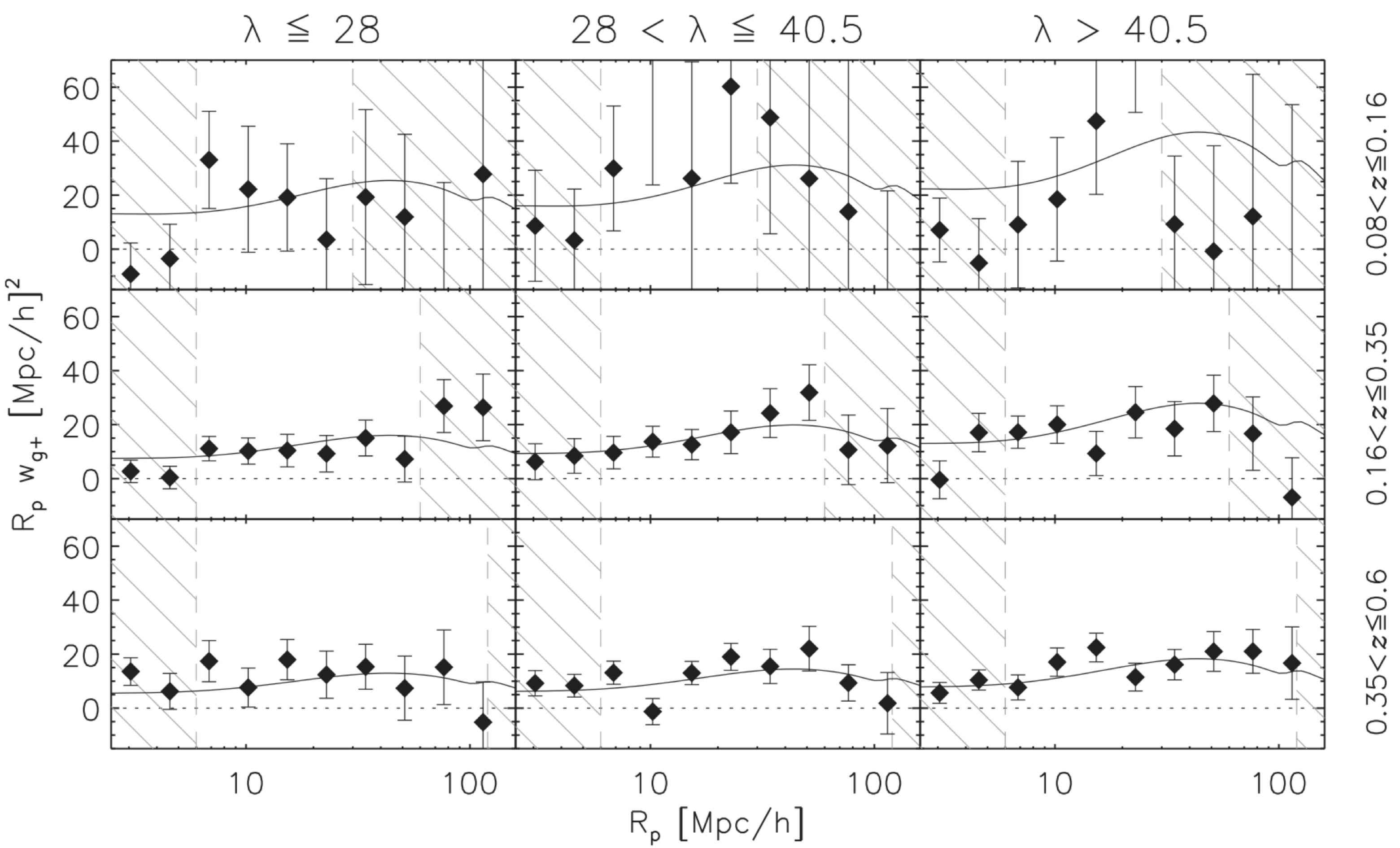
… possible to measure from observational data

⇨ Is it possible to detect GI/II signals from the observable tracers??

Observational results also suffer from projection effects

GI correlations from the subhalo/satellite distribution

Cluster shape – density correlation traced by the cluster members (redMaPPer)

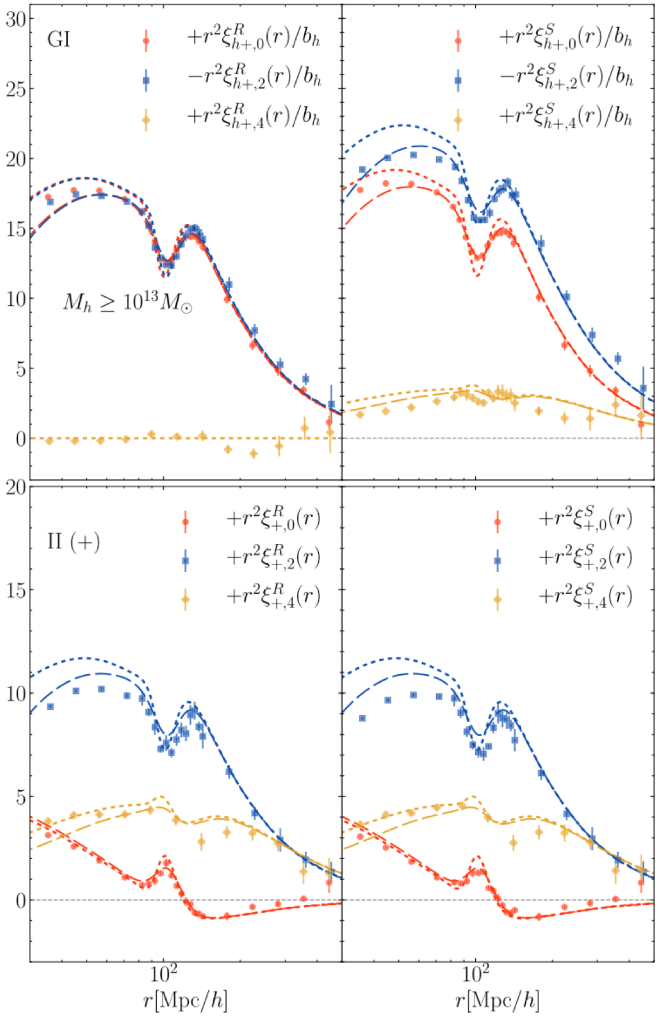


Pioneering observational study of GI correlation between halo shape and density fluctuation

van Uitert & Joachimi (2017)

Our motivation of IA study

Constraints on cosmologies from precise measurements of IA correlations



Okumura, Taruya, & Nishimichi (2020)

- We aim to constrain cosmology from high-quality GI correlations

  Detecting the BAO feature at ~ 100 Mpc/h

- GI / II correlations using BOSS and/or HSC data

  Before analyzing the real observational data, we demonstrate the detectability of IA signals and quantitative estimation of projection effects using *N*-body simulations

N-body simulations and subhalo catalogues

A part of the Dark Quest II Project (Nishimichi+, in prep.)

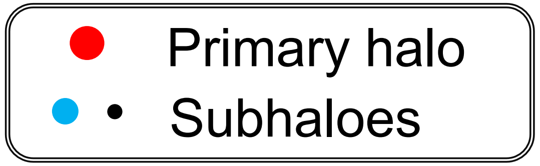
- L_{box} : 1000.0 [Mpc/h]
- N_{part} : 3000^3
- M_{part} : 3.23×10^9 [$M_\odot$/h]
- Planck 2018 cosmological parameters
- 3 independent runs for error estimation
- Redshift: 0.000, 0.312, 0.516, 0.741, 1.000

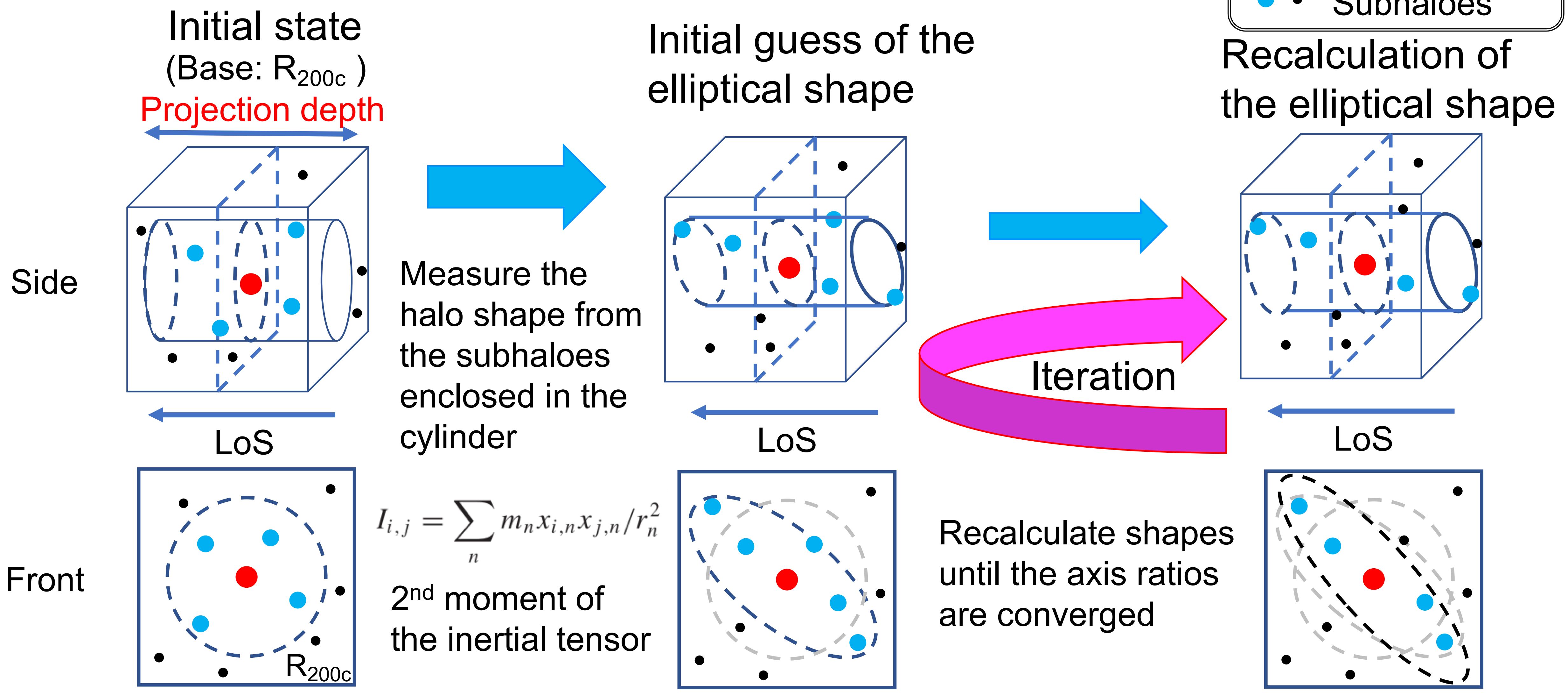
Haloes are identified by the Rockstar halo finder

- Primary haloes ⇨ Measure shapes by the subhalo distribution
- Primary haloes + subhaloes ($M_h > 10^{11}$ $h^{-1}M_{sun}$) ⇨ Tracers of background density field

Shape measurements of primary haloes

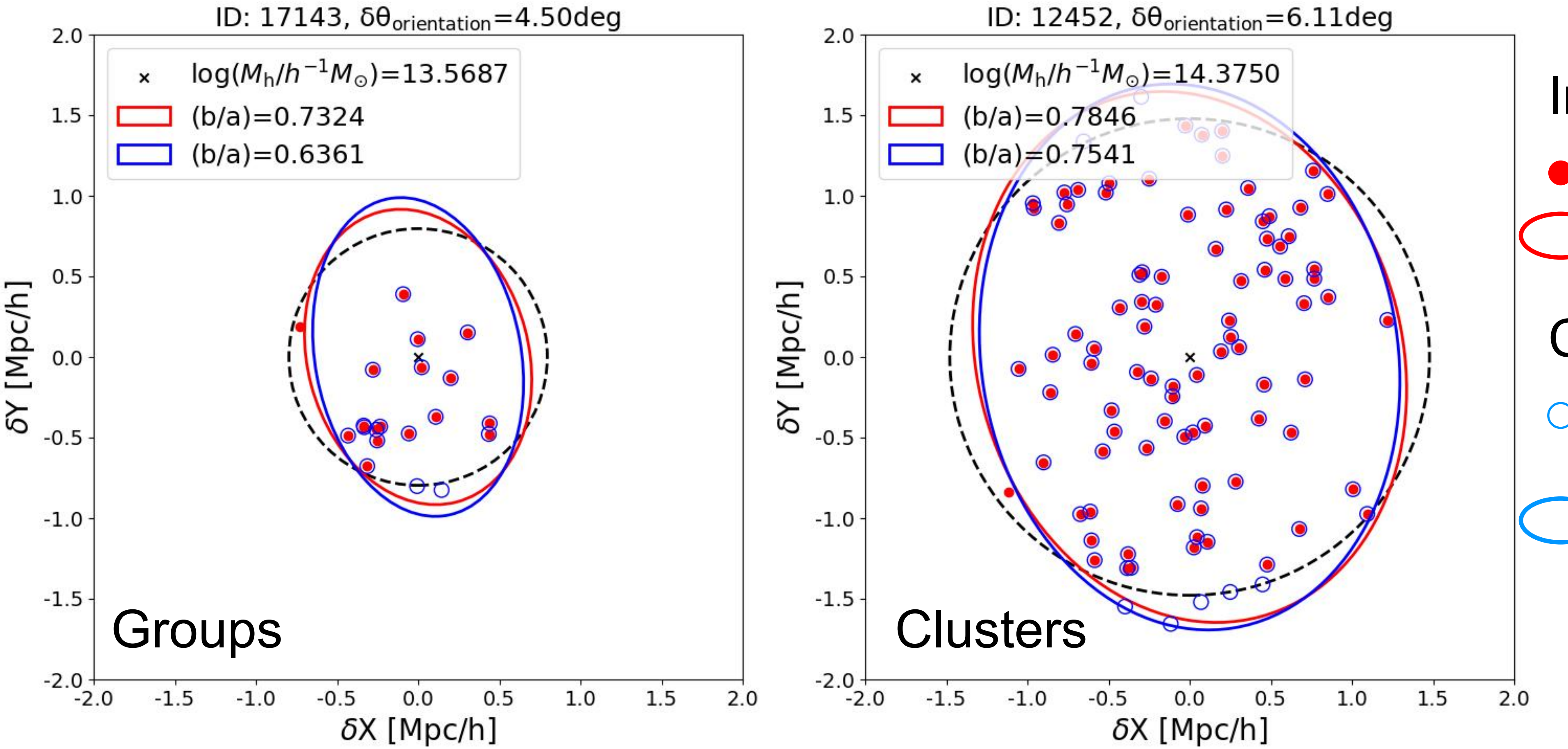
Halo shapes are evaluated from the projected subhalo distribution





N-body simulations and subhalo catalogues

Some examples of determining halo shapes from subhalo distribution



Initial guess:

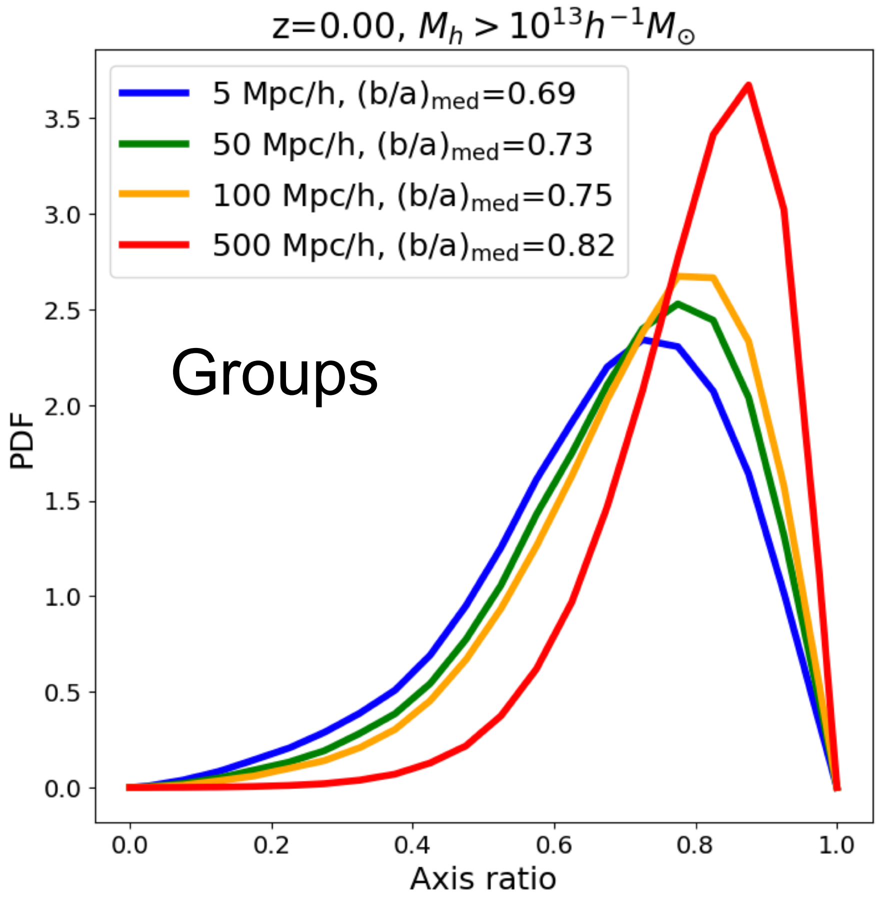
- Subhaloes enclosed by R_{200c}
- Initial halo shape

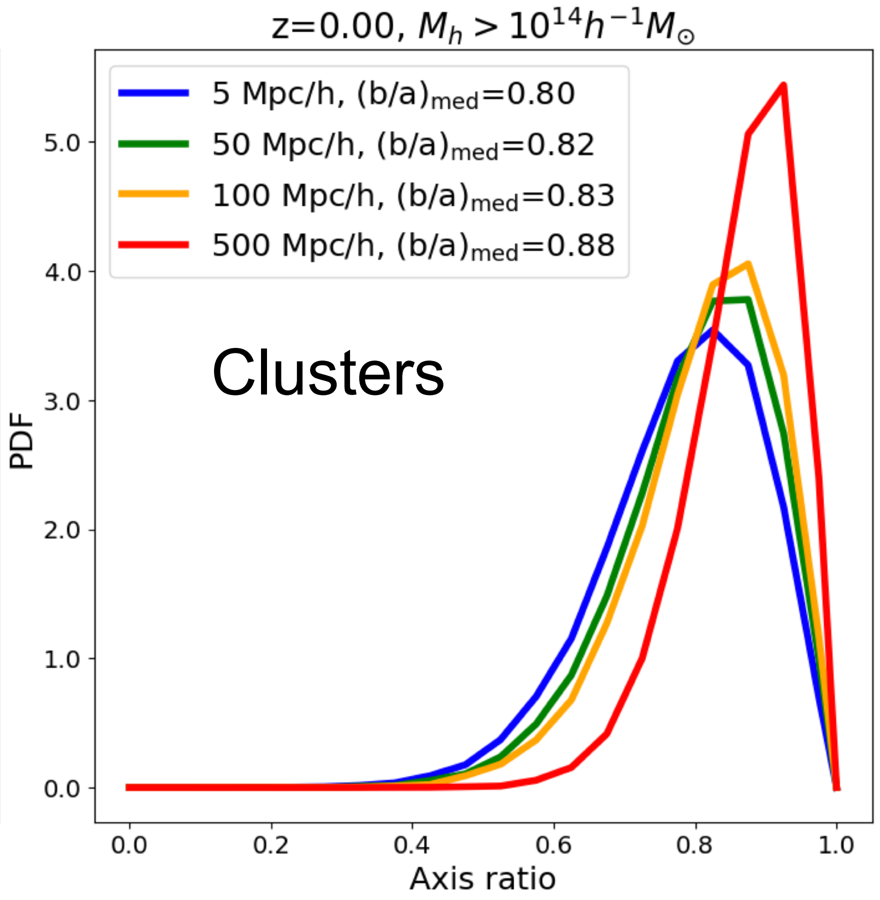
Converged shape:

- Subhaloes used to determine the converged shapes
- Converged halo shapes

Shape measurements of primary haloes

Projection effect reduces the intrinsic ellipticities and the GI correlations





Intrinsic ellipticities:

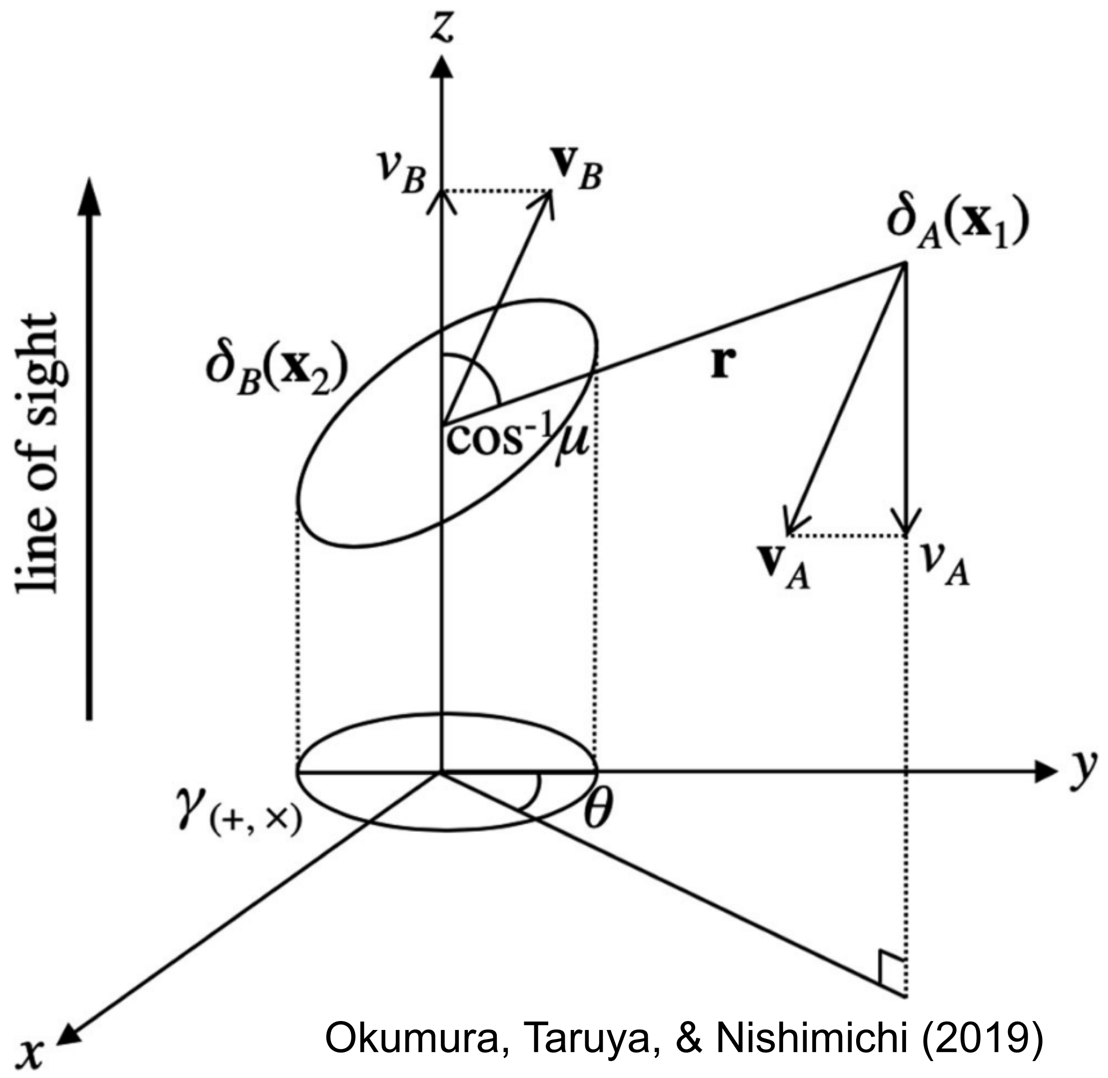
$$\gamma_+(r) = \frac{1-(b/a)^2}{1+(b/a)^2}\cos\theta$$

GI correlations:

$$\xi_{h+}(r) = \frac{1}{RR(r)}\sum_r \gamma_+(r)$$

Projected halo shape – density correlation

Projecting halo shapes on celestial sphere



Okumura, Taruya, & Nishimichi (2019)

1. Determining 2D halo shapes on the celestial sphere

2. Measuring the distances and angles between major axes of haloes and density field (haloes with $M_h > 10^{11}\, h^{-1} M_{sun}$)

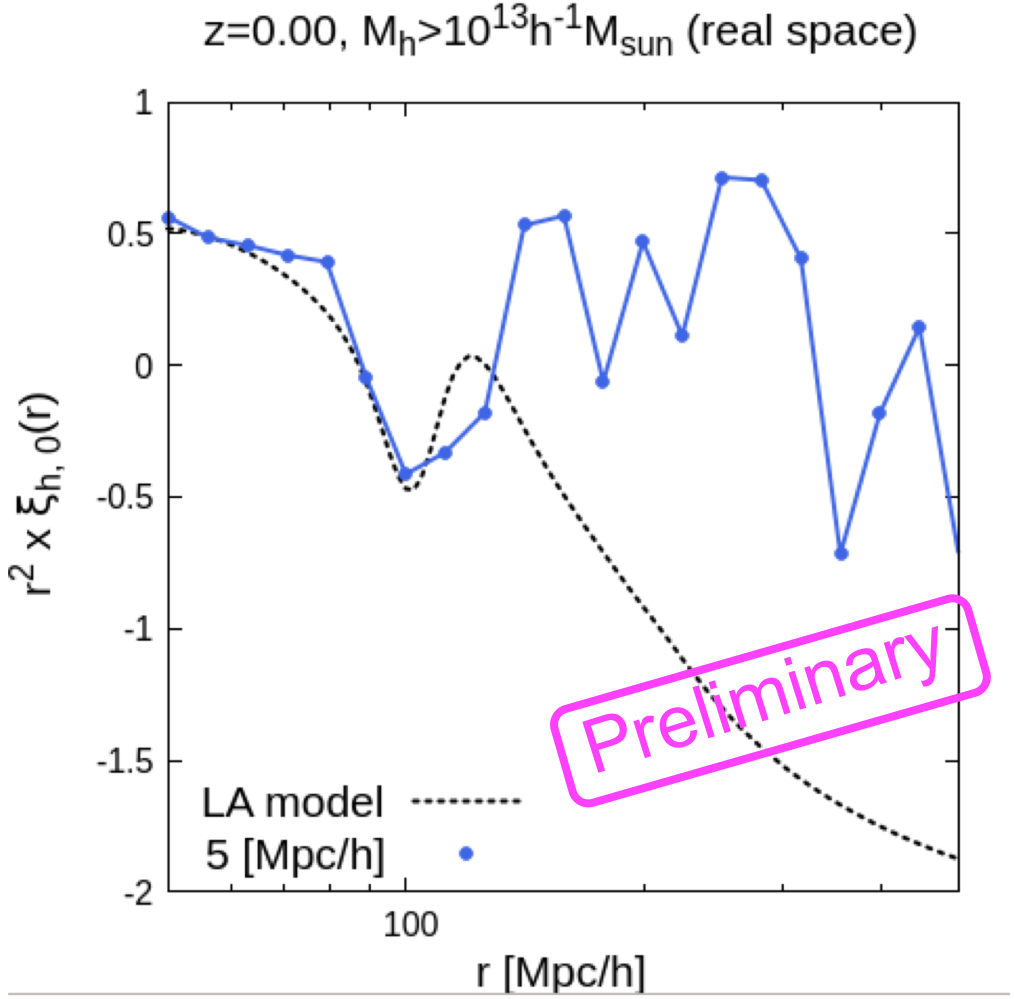
3. Evaluating GI correlations using the following estimator:

$$\xi_{\delta_A +}(r) = \frac{\sum_{i,j|r} \gamma_+(j|i)}{R_A R_B(r)}$$

Mandelbaum et al. (2006)

GI correlations in real space

GI correlation of group-scale haloes in real space



- LA model represents the GI correlation (up to ~100 Mpc/h) of small projection depth

$$\xi^{\mathrm{R}}_{\mathrm{h}+}(\boldsymbol{r}) = \widetilde{C}_1 b_{\mathrm{h}}(1-\mu^2)\Xi^{(0)}_{\delta\delta,2}(r)$$

$$\Xi^{(n)}_{XY,\ell}(r) = (aHf)^n \int_0^\infty \frac{k^{2-n}\mathrm{d}k}{2\pi^2} P_{XY}(k) j_\ell(kr),$$

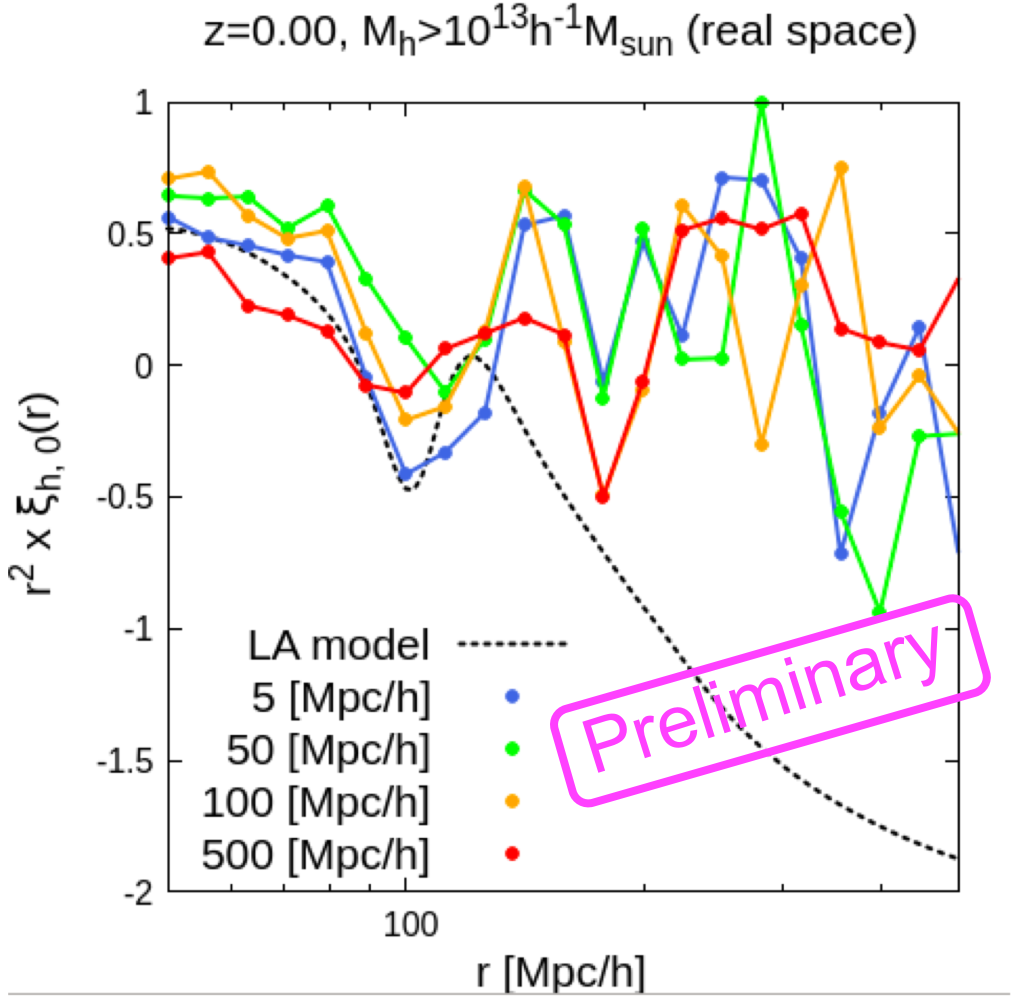
Okumura & Taruya (2020)

- The BAO trough can be measured

- Error estimation is required for quantitative discuss of this result

GI correlations in real space

GI correlations of group-scale haloes by varying projection depths in real space

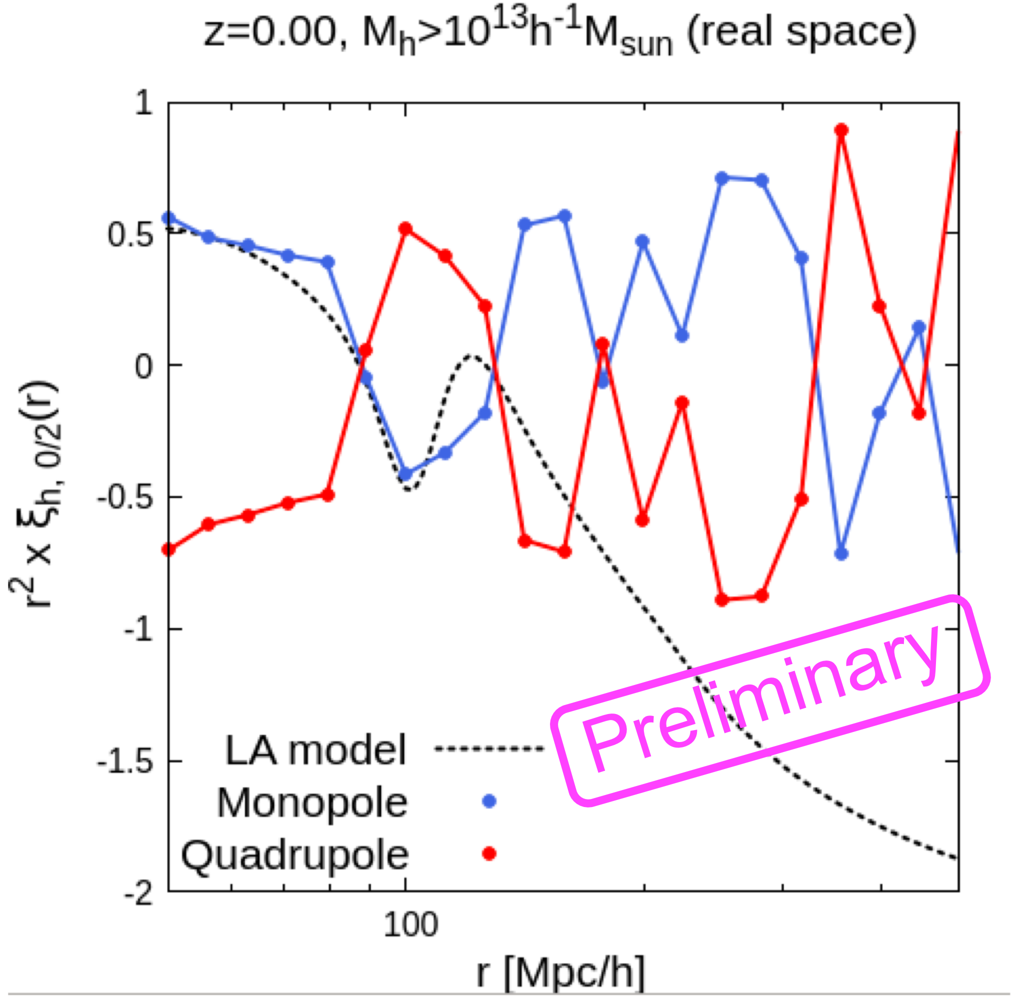


- The BAO troughs are damped by increasing the projection depth

- Error estimations are required for quantitative discuss of these results again…

Multipole expansions of GI correlations in real space

Multipole components of the GI correlation of group-scale haloes (5 Mpc/h projection)



Expanding the multipole components:

$$\xi_{\mathrm{h}+,\ell}(r) = \frac{2\ell+1}{2}\frac{1}{RR(r)}\sum_{i,j|r=|\boldsymbol{x}_j-\boldsymbol{x}_i|}\gamma_+(\boldsymbol{x}_j)\mathcal{P}_\ell(\mu_{ij})$$

Okumura & Taruya (2020)

Consistent with the prediction of the LA model

$$\xi^{\mathrm{R}}_{\mathrm{h}+,0}(r) = -\xi^{\mathrm{R}}_{\mathrm{h}+,2}(r) = \frac{2}{3}\widetilde{C}_1 b_{\mathrm{h}}\,\Xi^{(0)}_{\delta\delta,2}(r)$$

Okumura & Taruya (2020)

Summary and future tasks

Summary

- We have measured shapes of dark haloes traced by the subhalo distribution with varying the projection depth
- The GI correlations are consistent with the LA model up to ~100 Mpc/h
- The BAO troughs can be detected, but the amplitude is damped by increasing the projection depth

Future tasks

We will

- estimate errors of GI correlations
- calculate GI correlations in redshift space
- calculate II correlations and check if the BAO troughs will be also detected

Real space

$$s = r + \frac{v_{Los}(r)}{aH(z)}\hat{z}$$

Redshift space