Modeling Intrinsic Galaxy Alignment

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collaborators:

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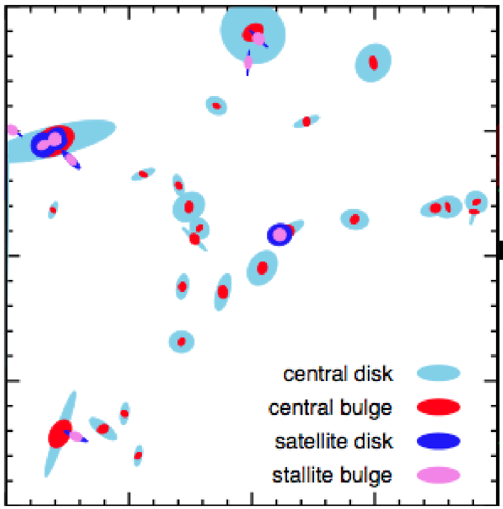
observational data provided by Singh & Mandelbaum

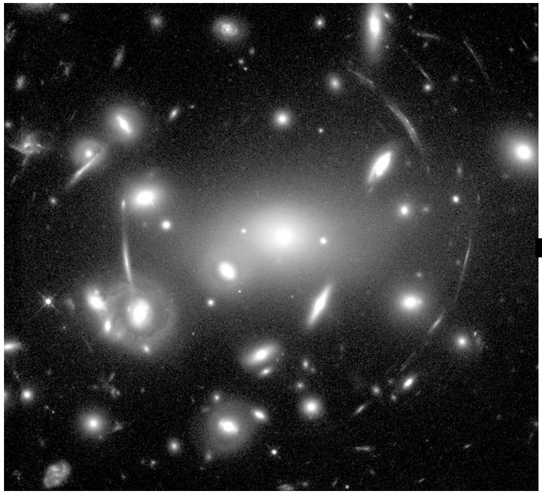
intrinsic alignment problem

background galaxies



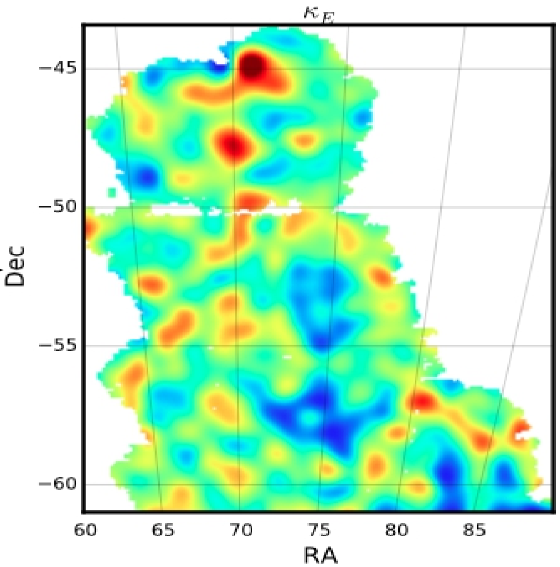
MICE simulation

gravitational lensing by foreground mass



HST observation (Couc, Ellis and NASA/ESA)

map of foreground mass



DES SV observation (Chang et al. 2015)

- ***goal of weak lensing surveys*** *(CFHTLS, DES, PFS, Euclid,..)*

  lensing map -> growth of structure -> cosmological constraints

- **problem**: alignment of background images results from lensing **and** intrinsic alignment

IA contamination in shear correlation

shear definition

$$\vec{\gamma} = \begin{pmatrix} \gamma_1 \\ \gamma_2 \end{pmatrix} \equiv \frac{(1-\overset{\substack{\text{2D axis ratio } q=b/a \\ \downarrow}}{q^2})}{(1+q^2)} \begin{pmatrix} \cos(2\overset{\substack{\text{position angle} \\ \downarrow}}{\alpha}) \\ \sin(2\alpha) \end{pmatrix}$$

IA contribution

$$\gamma^{obs} = \gamma + \gamma^I$$

shear correlation

$$\langle \gamma_i^{obs} \gamma_j^{obs} \rangle = \underbrace{\overset{\text{GG}}{\langle \gamma_i \gamma_j \rangle}}_{\text{lensing signal}} + \underbrace{\overset{\text{GI}}{\langle \gamma_i \gamma_j^I \rangle} + \overset{\text{IG}}{\langle \gamma_i^I \gamma_j \rangle} + \overset{\text{II}}{\langle \gamma_i^I \gamma_j^I \rangle}}_{\text{IA contamination}}$$

need for fast alignment modeling

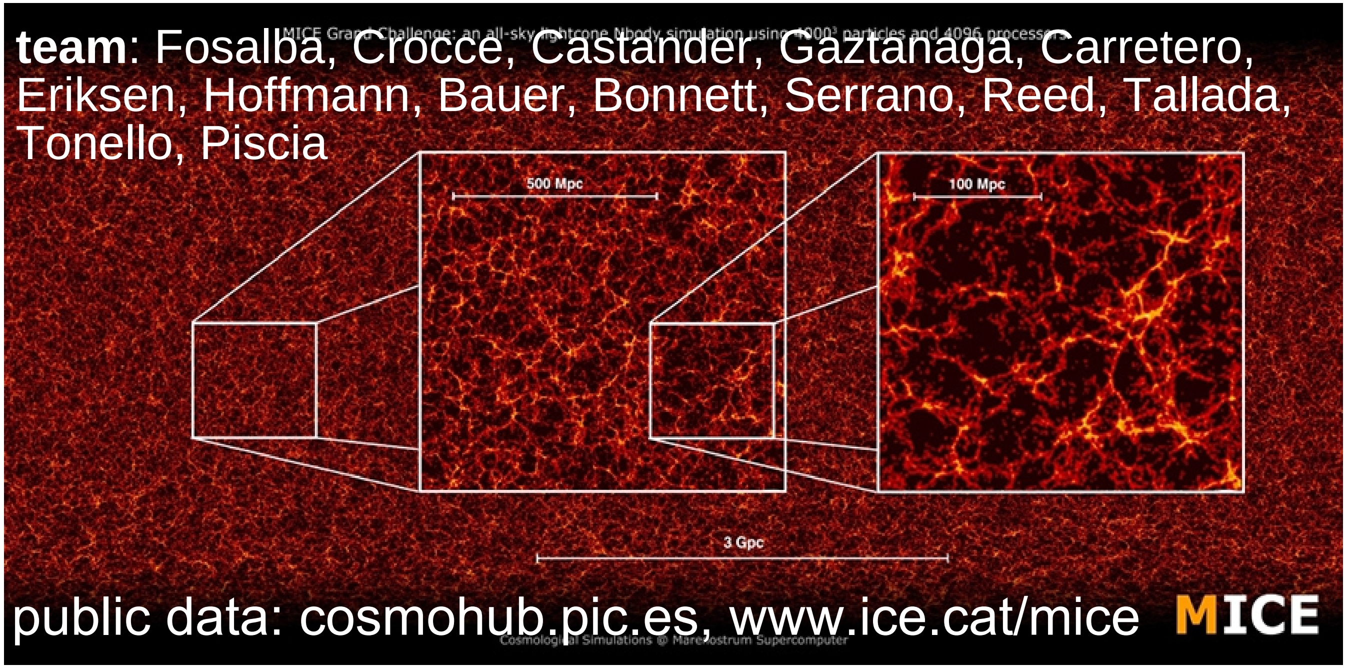
- future and ongoing lensing surveys cover volumes of several $(\mathrm{Gpc}/h)^3$

  -> large mock catalogs with IA needed for testing
    - IA corrections from analytical models
    - analysis pipelines

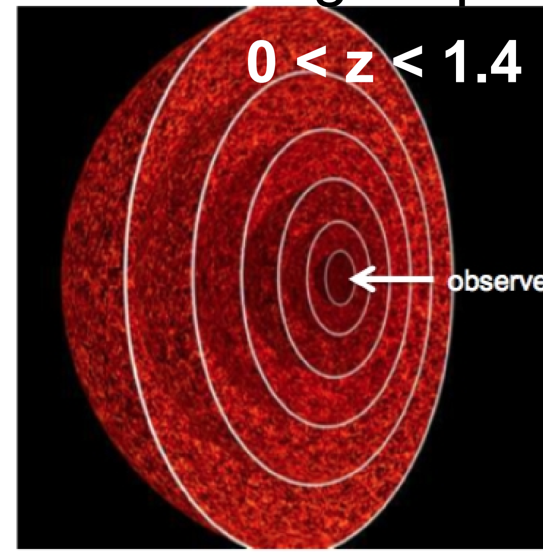
  -> hundreds of mock needed for covariance estimation

- hydro-simulations only possible for “small” volumes

MICE Grand Challenge simulation



light-cone output & lensing map



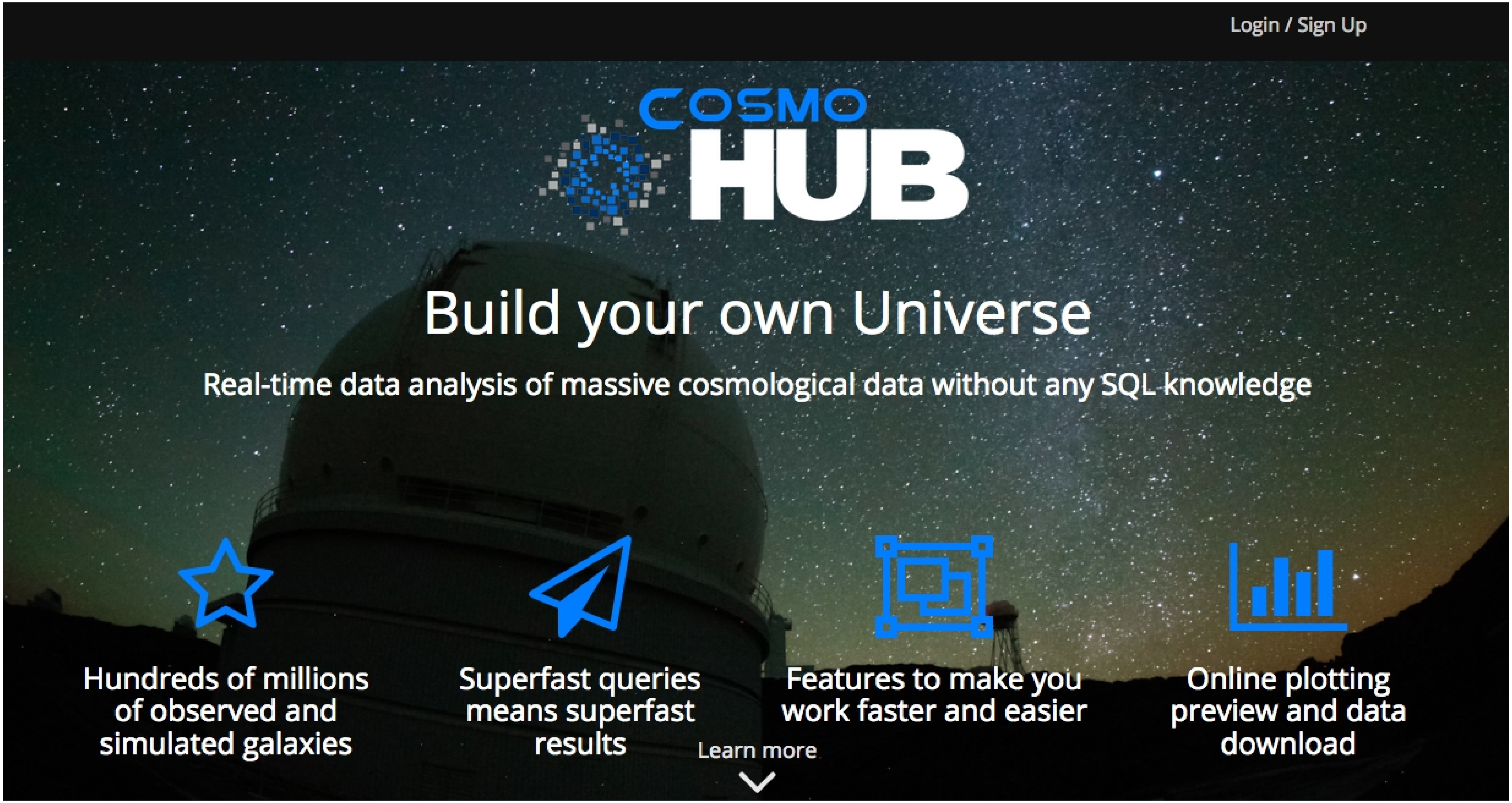
Fosalba et al. 08, [MNRAS, 391, 435]

- 4096^3 (7 10^{10}) particles
- particle mass = 3 10^{10} Msun/h
- simulation box (3 Gpc/h)^3
- ΛCDM cosmology:

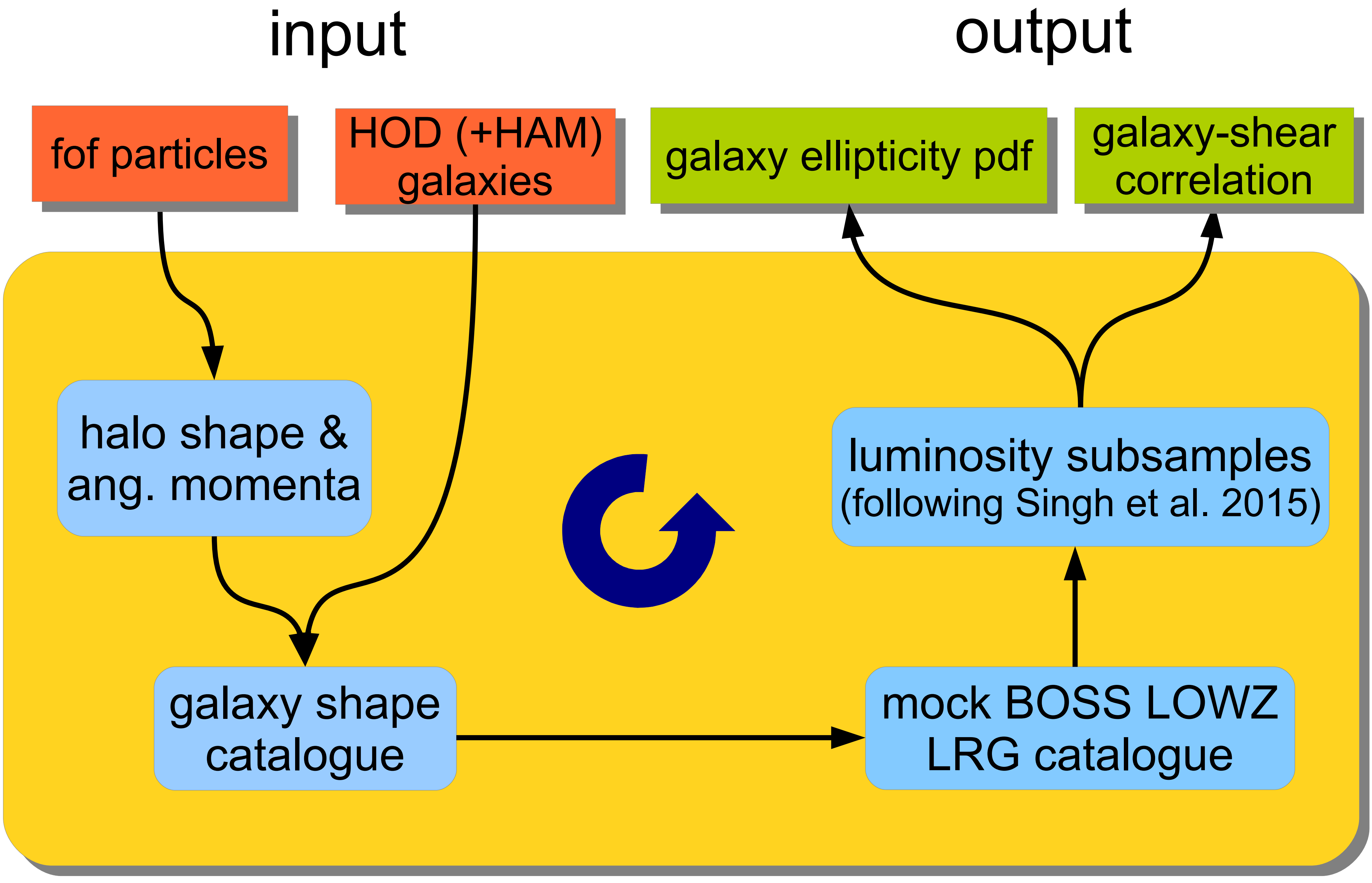
$$\Omega_m=0.25, \Omega_\Lambda=0.75\,\Omega_b=0.044, \sigma_8=0.8\,n_s=0.95, h=0.7$$

- FoF halos populated with galaxies (HOD + HAM)
- reproduce Colour & magnitude dependence of SDSS 2pt correlation

https://cosmohub.pic.es



IA pipeline



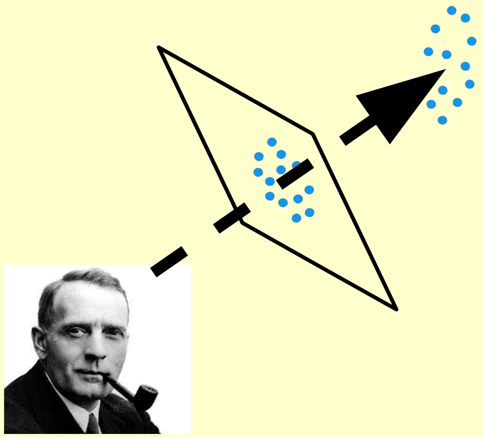
input
output
fof particles
HOD (+HAM) galaxies
galaxy ellipticity pdf
galaxy-shear correlation
halo shape & ang. momenta
luminosity subsamples (following Singh et al. 2015)
galaxy shape catalogue
mock BOSS LOWZ LRG catalogue

measuring halo properties

angular momentum

$$\boldsymbol{J} = \frac{1}{N_p}\sum_{i=1}^{N_p} \boldsymbol{r}_n \times \boldsymbol{v}_n$$

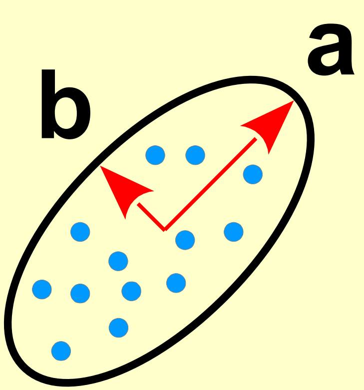
2D shapes and orientations



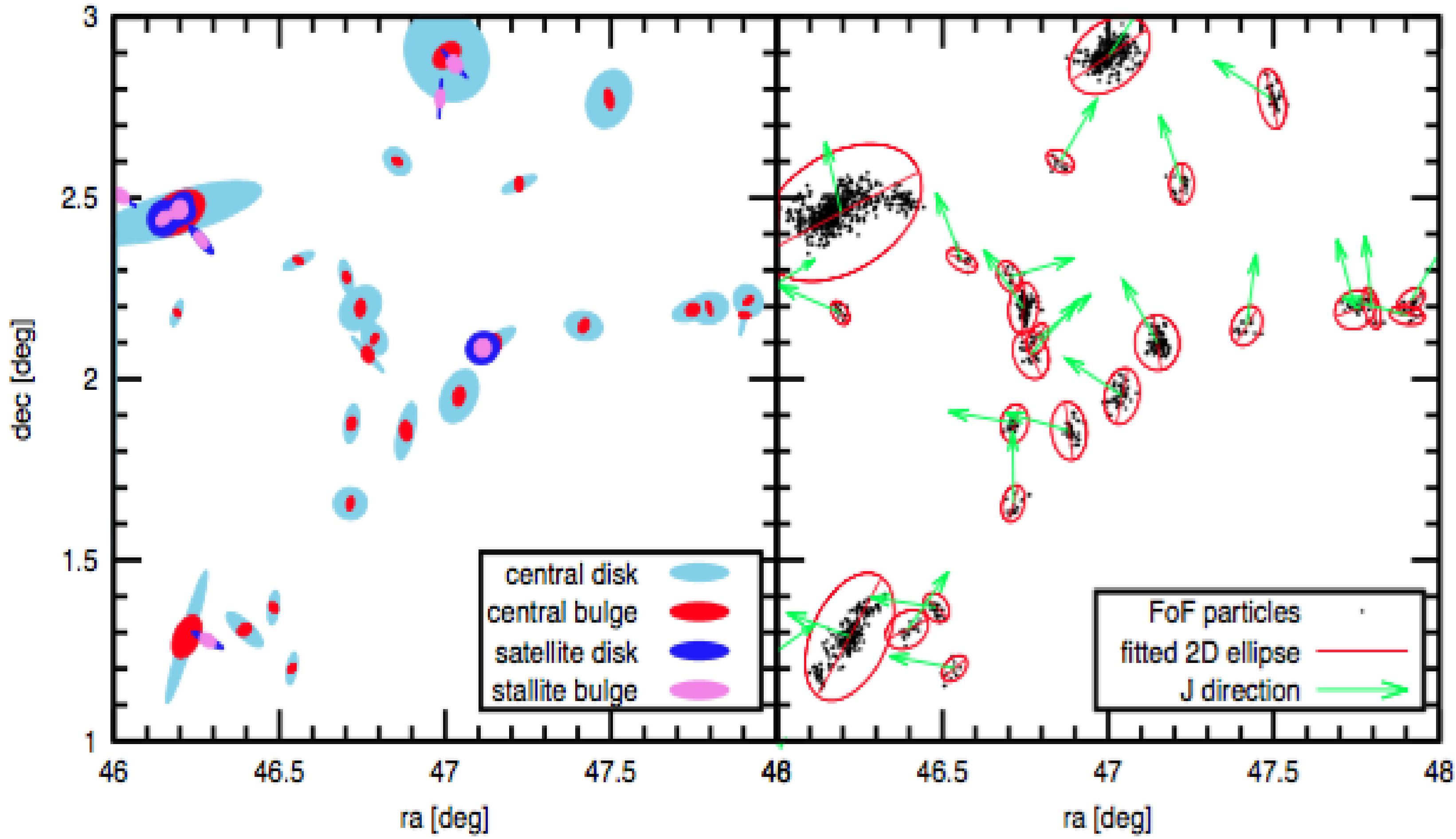
- project halo particles on tangential plane
- measure **major and minor axis: a & b** (eigenvectors of red. moment of inertia)

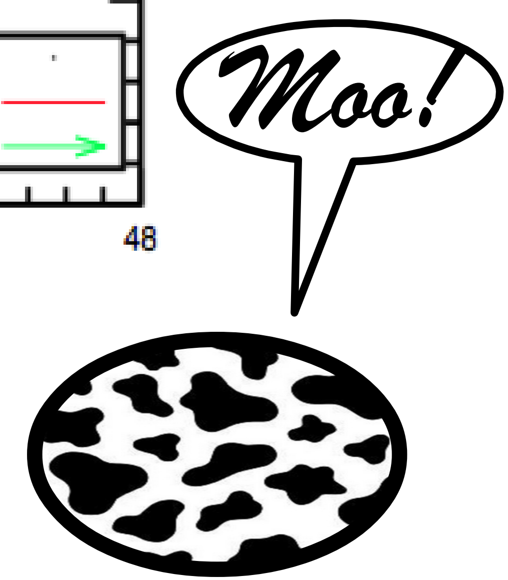
$$I_{ij} = \sum_n^{N_p} m_n \frac{x_{n,i}\, x_{n,j}}{r_n^{\;2}}$$

- shapes quantified by axis ratio q = |**b**|/|**a**|



elliptical cow approximation





model for galaxy shapes

following Joachimi et al. 2013/14 (arXiv:1203.6833, 1305.5791)

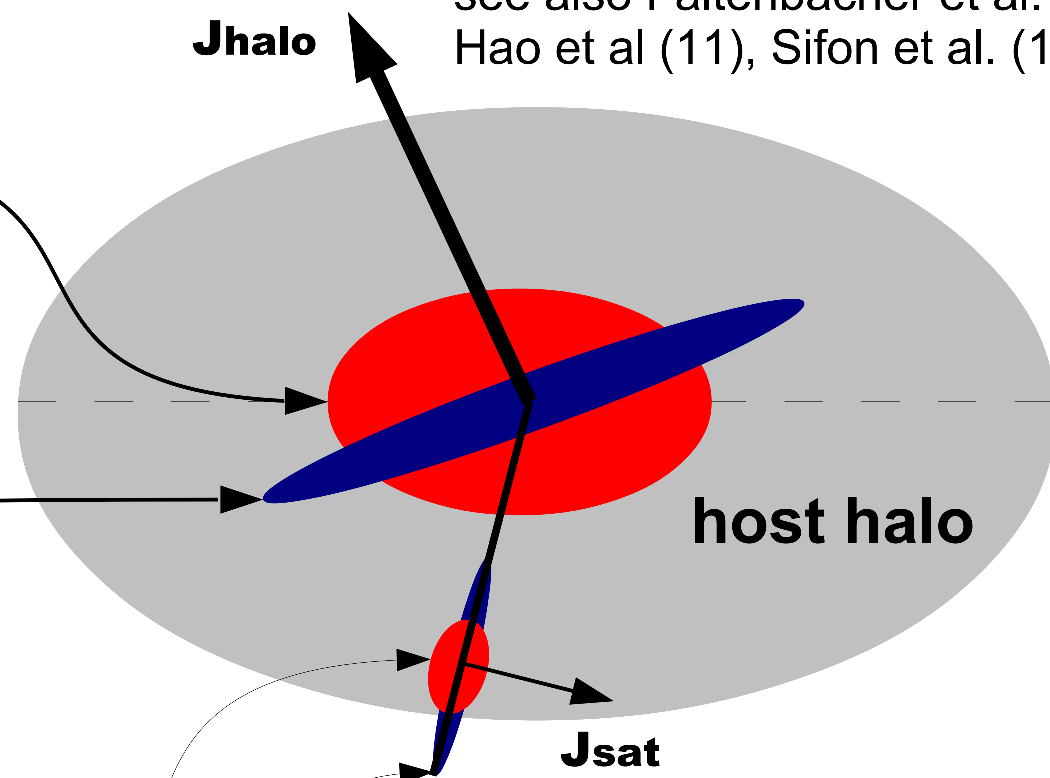
see also Faltenbacher et al. (07,08)
Hao et al (11), Sifon et al. (14)

red centrals

- same 2D shape and orientation as host halo

blue centrals

- perpendicular to 3D angular momentum of host halo



red satellites

- pointing to halo center
- shape from halo shape pdf

blue satellites

- pointing to halo center

- colour defined by g-r cut
- disk thickness drawn from gaussian distribution
- **orientations randomized to decrease IA signal**

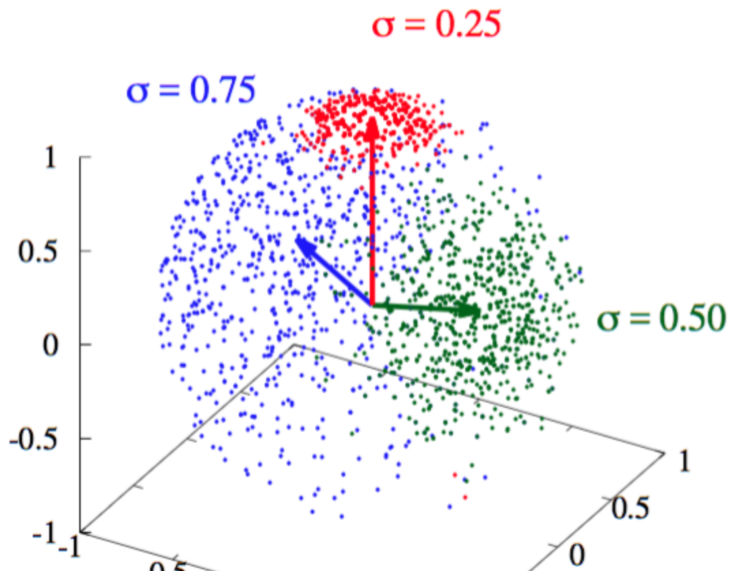
fun fact

Model is wrong

... works anyway!

modeling intrinsic miss alignment

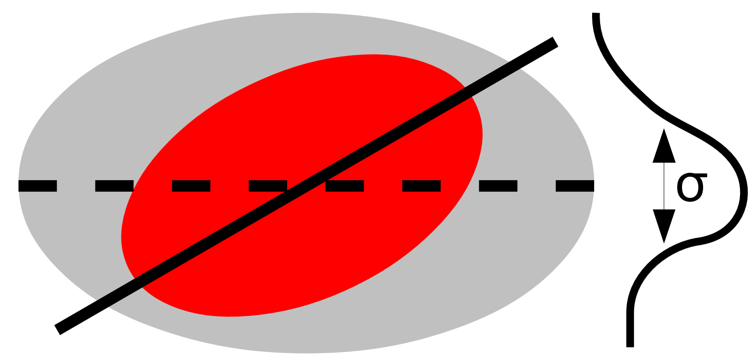
satellites and central disks
randomizing 3D orientations



Misis-Fisher distribution

$$P(\cos\vartheta) = \frac{1}{2\sigma^2 \sinh \sigma^{-2}} \exp\left(\frac{\cos\vartheta}{\sigma^2}\right)$$

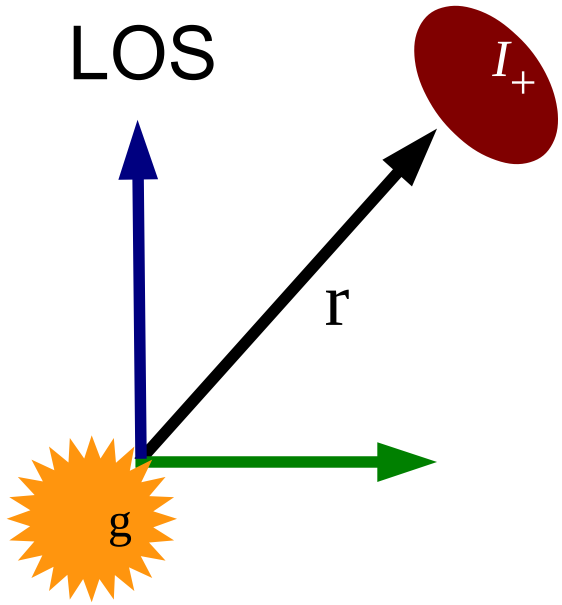
central ellipse
randomizing 2D orientations (gaussian around 0)



3 parameters for randomizing orientations:

1) central ellipse σ_{redcent} 2) central disk σ_{bluecent} 3) satellites σ_{sat}

measuring intrinsic alignment



2D galaxy-shear correlation

$$\xi_{g+}(\sigma,\Pi) = \langle \delta_g \gamma_+^I \rangle (\sigma,\Pi)$$

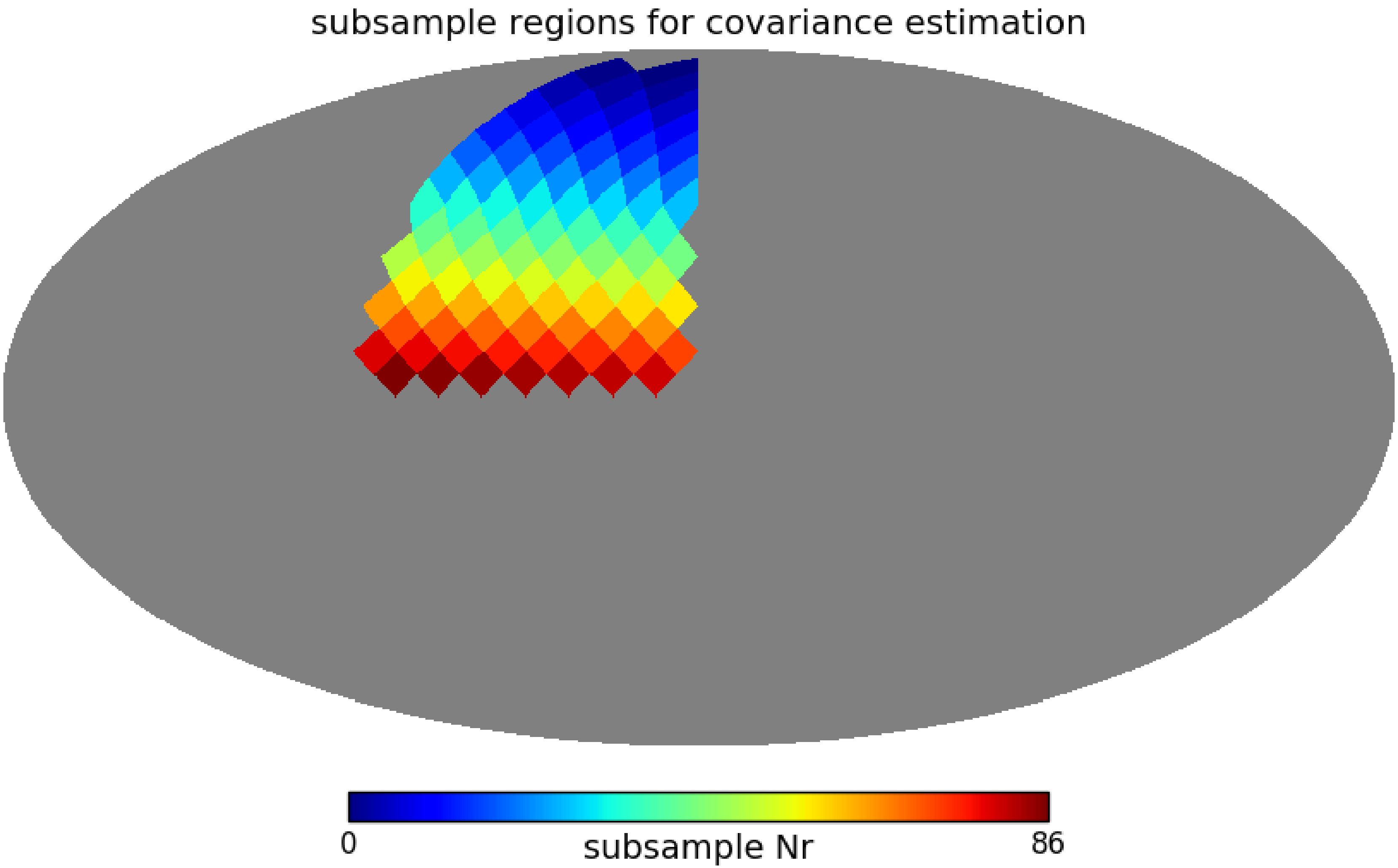
($^{I}_{+}$ and $_{g}$ are in same redshift bin)

projection along line of sight

$$w_{g+}(\sigma) = \int_{-\Pi_{max}}^{\Pi_{max}} \xi_{g+}(\sigma,\Pi) d\Pi$$

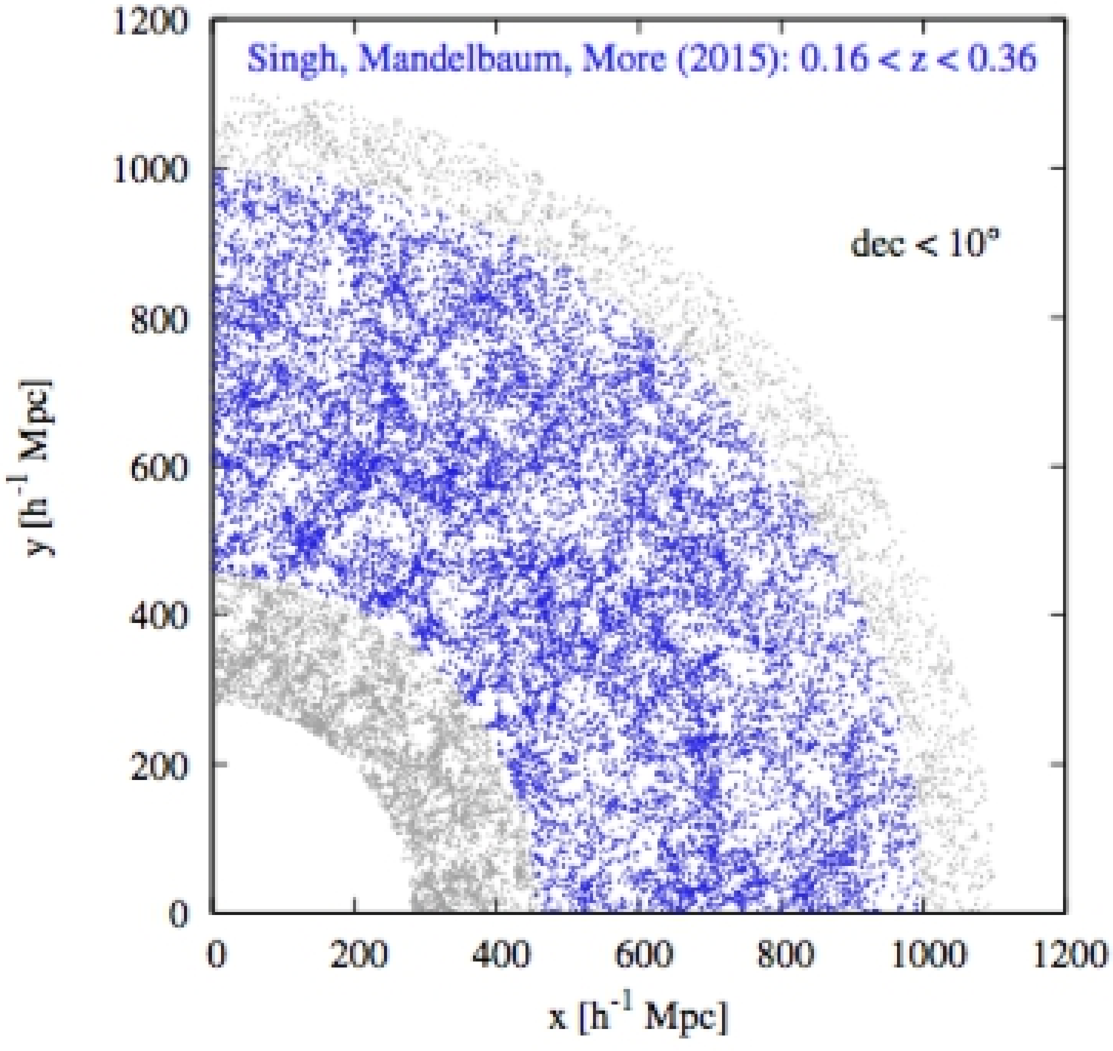
$_{\text{max}}$ = 60 Mpc/h

JK errors from HEALPix samples

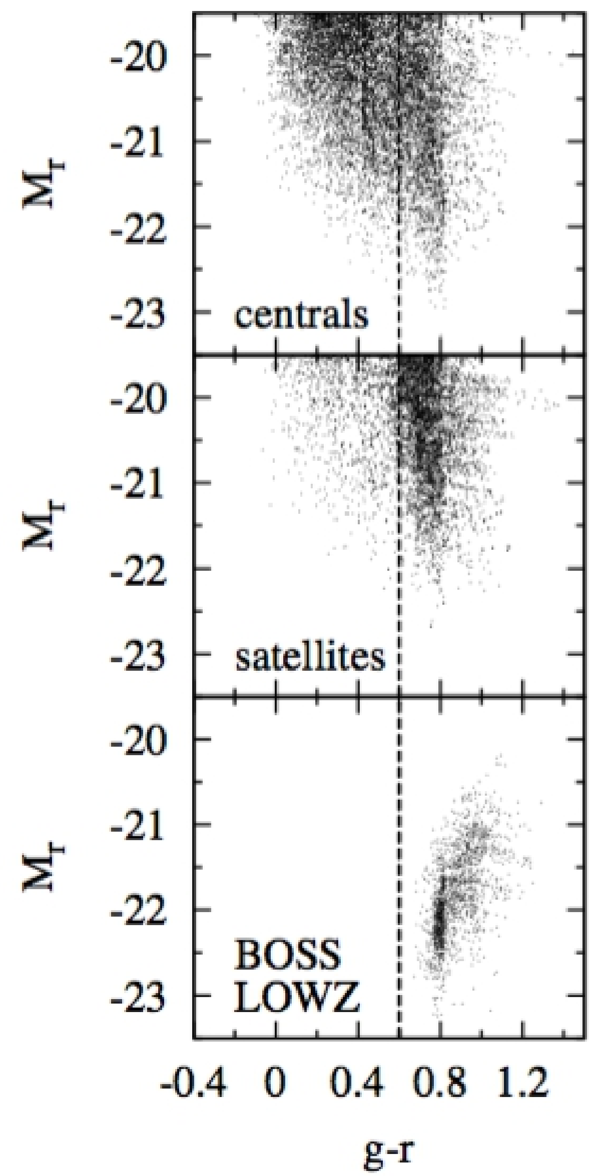


mock BOSS LOWZ catalogue

slice in MICE-GC light cone



MICECAT v2.0 galaxies



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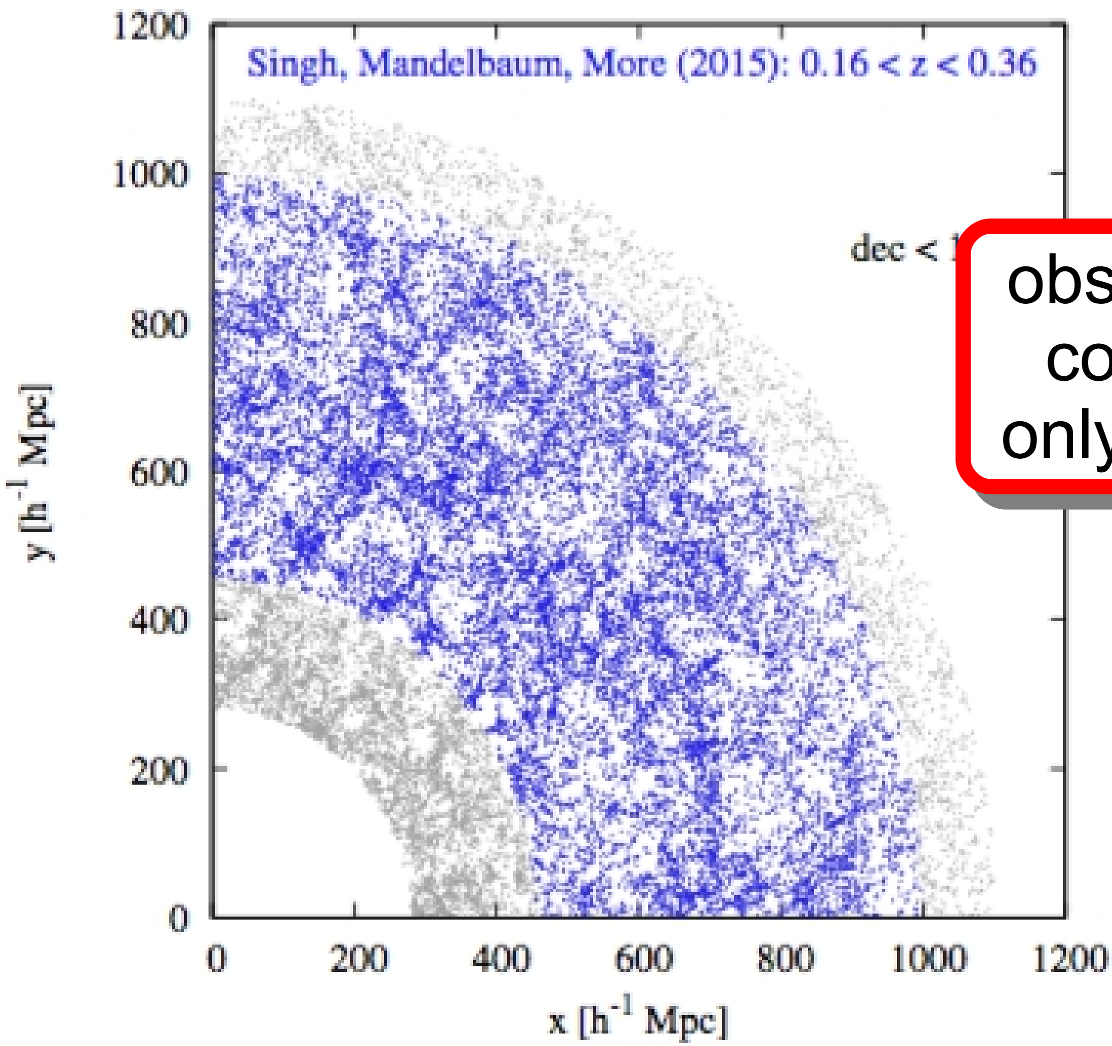
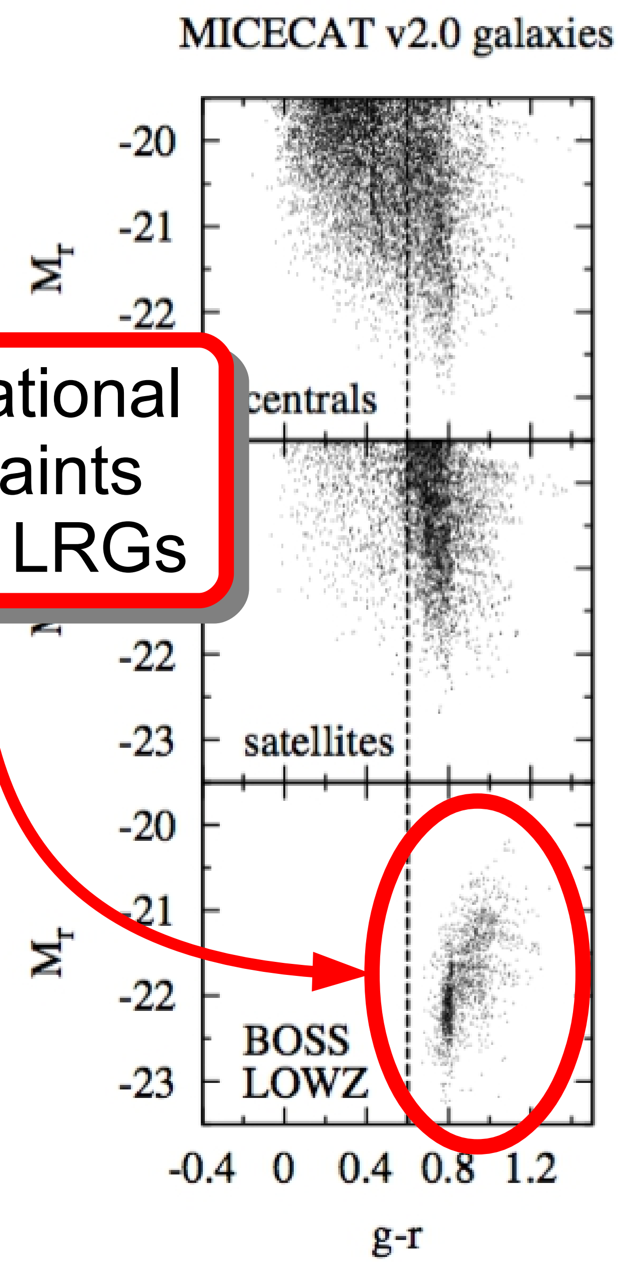
slice in MICE-GC light cone



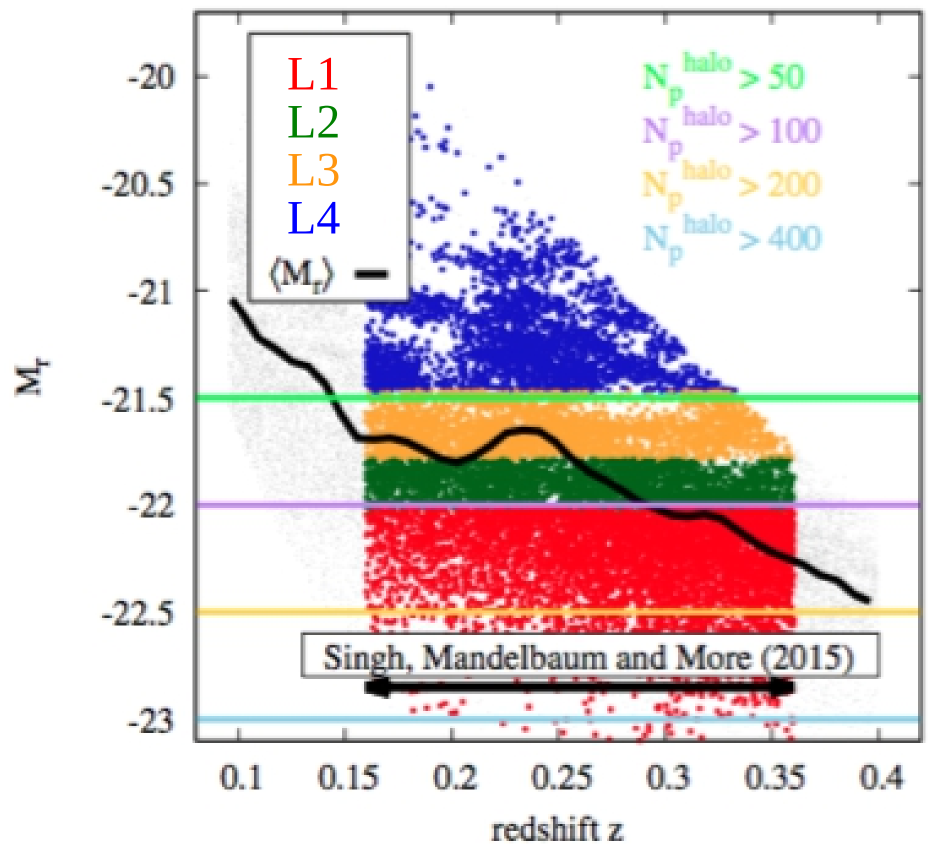


observational constraints only for LRGs

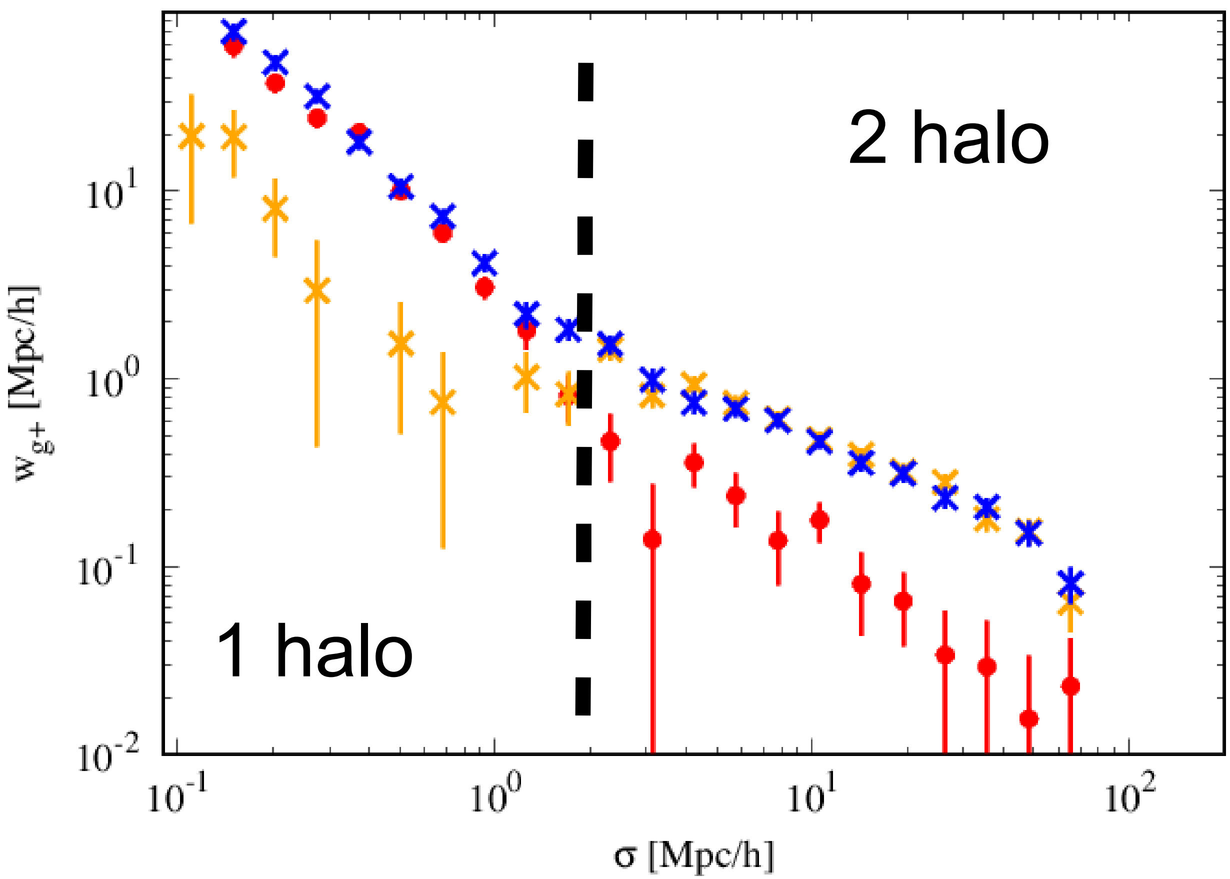
magnitude limited samples

following Singh, Mandelbaum, More 2015 (arXiv:1411.1755)

magnitude samples	cuts	BOSS LOWZ	mock BOSS LOWZ
full LOWZ		159621	129550
$L1$	$0\% - 20\%$	31910	25910
$L2$	$20\% - 40\%$	31910	25910
$L3$	$40\% - 60\%$	31910	25910
$L4$	$60\% - 100\%$	63830	51820



projected galaxy-shear correlation for different model parameters

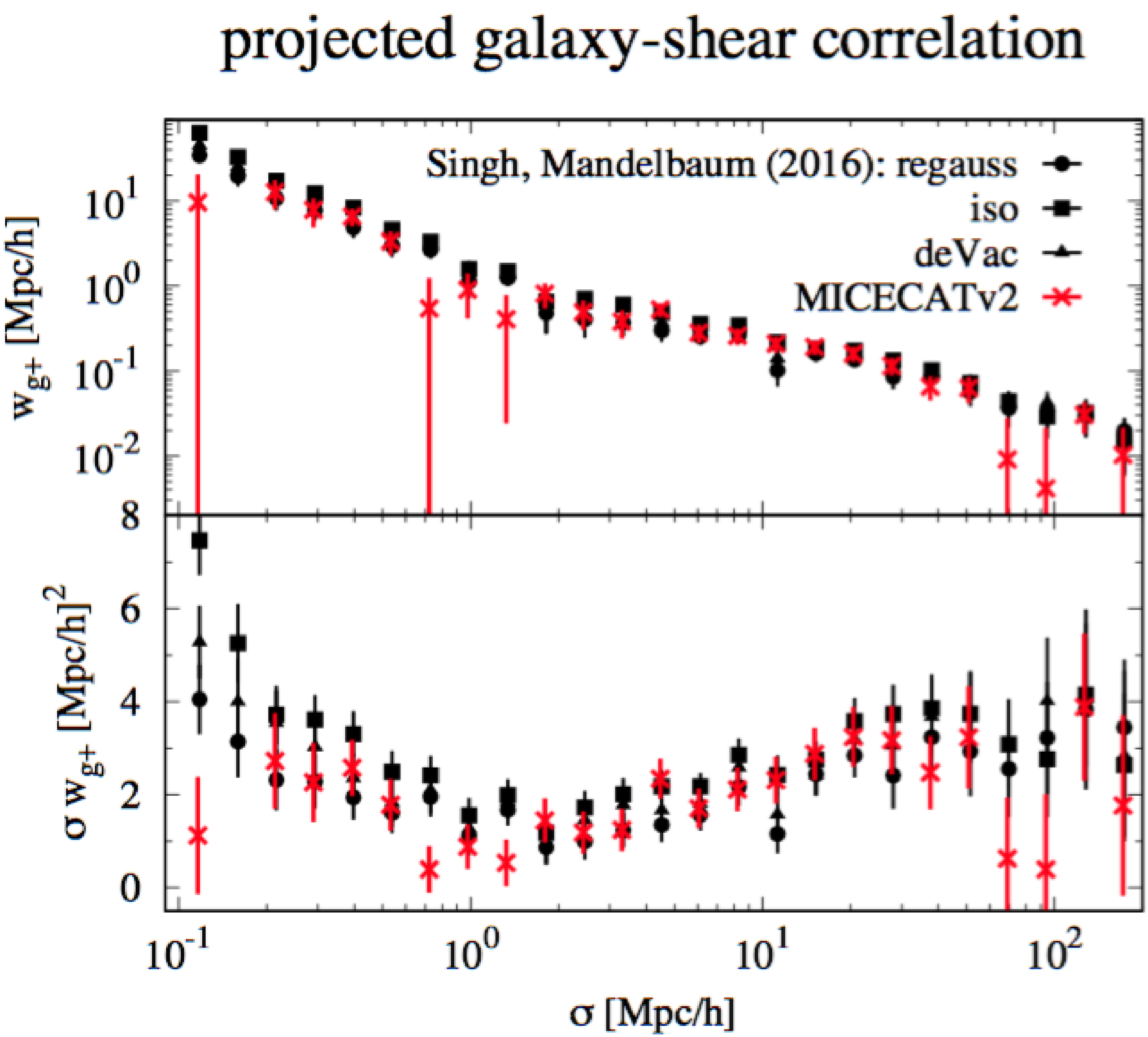


1- and 2-halo terms are (almost) independent

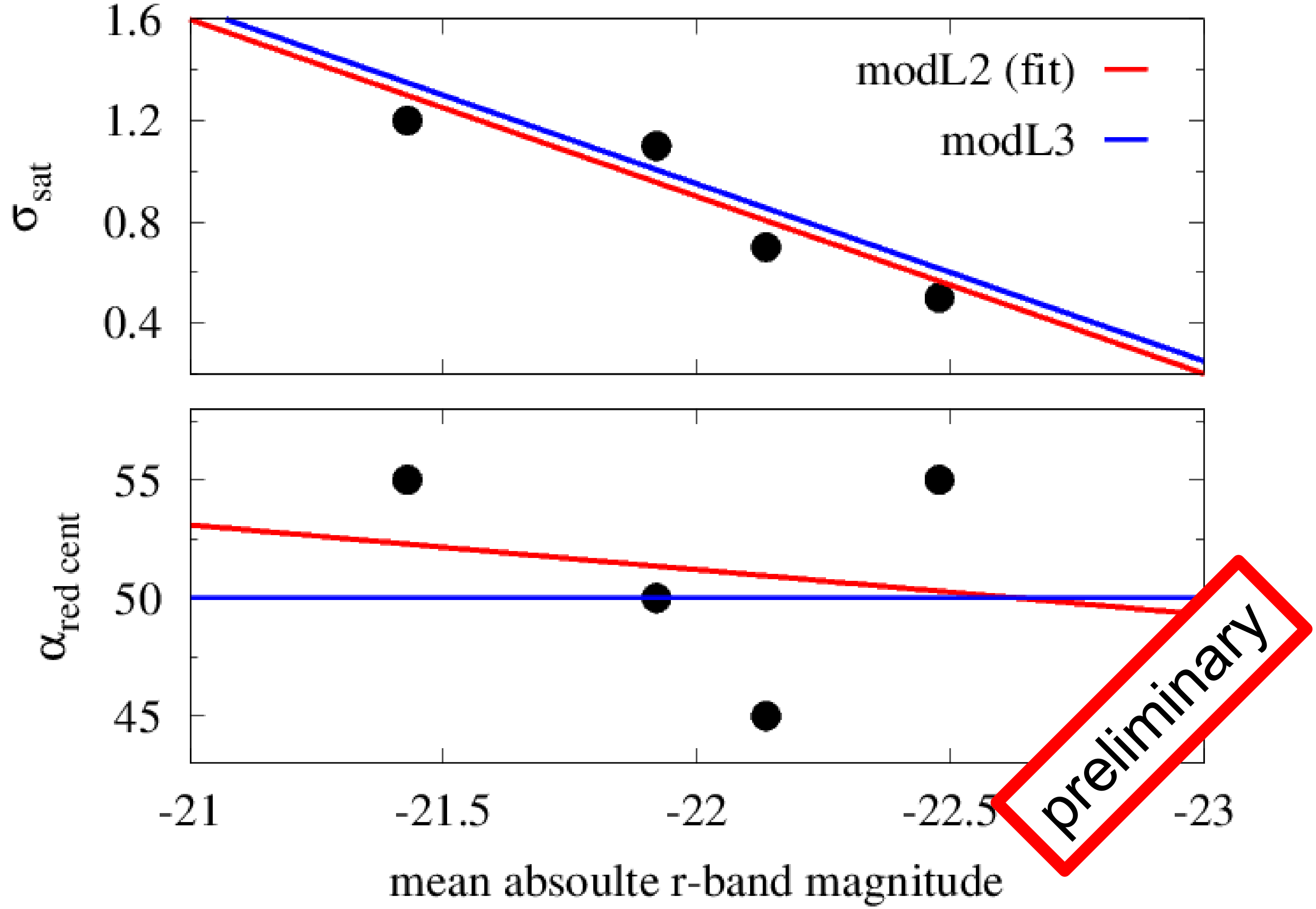
	model 1	model 2	model 3
randomizing central orientation	low	low	high
randomizing satellite orientation	low	high	low

comparison with BOSS LOWZ LRGs

Singh, Mandelbaum, More 2015/16 (arXiv:1411.1755, 1510.06752)

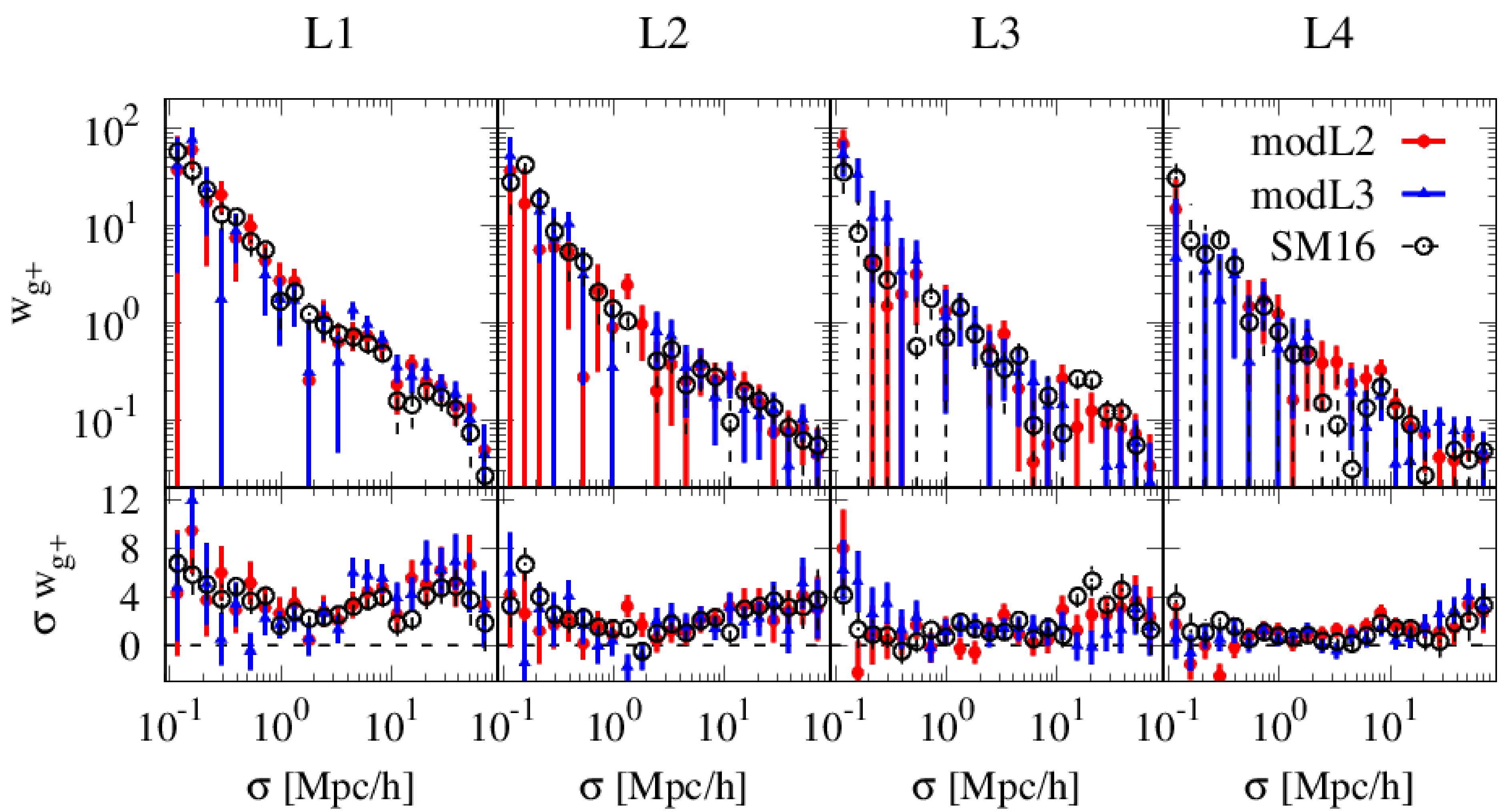


luminosity dependent IA model

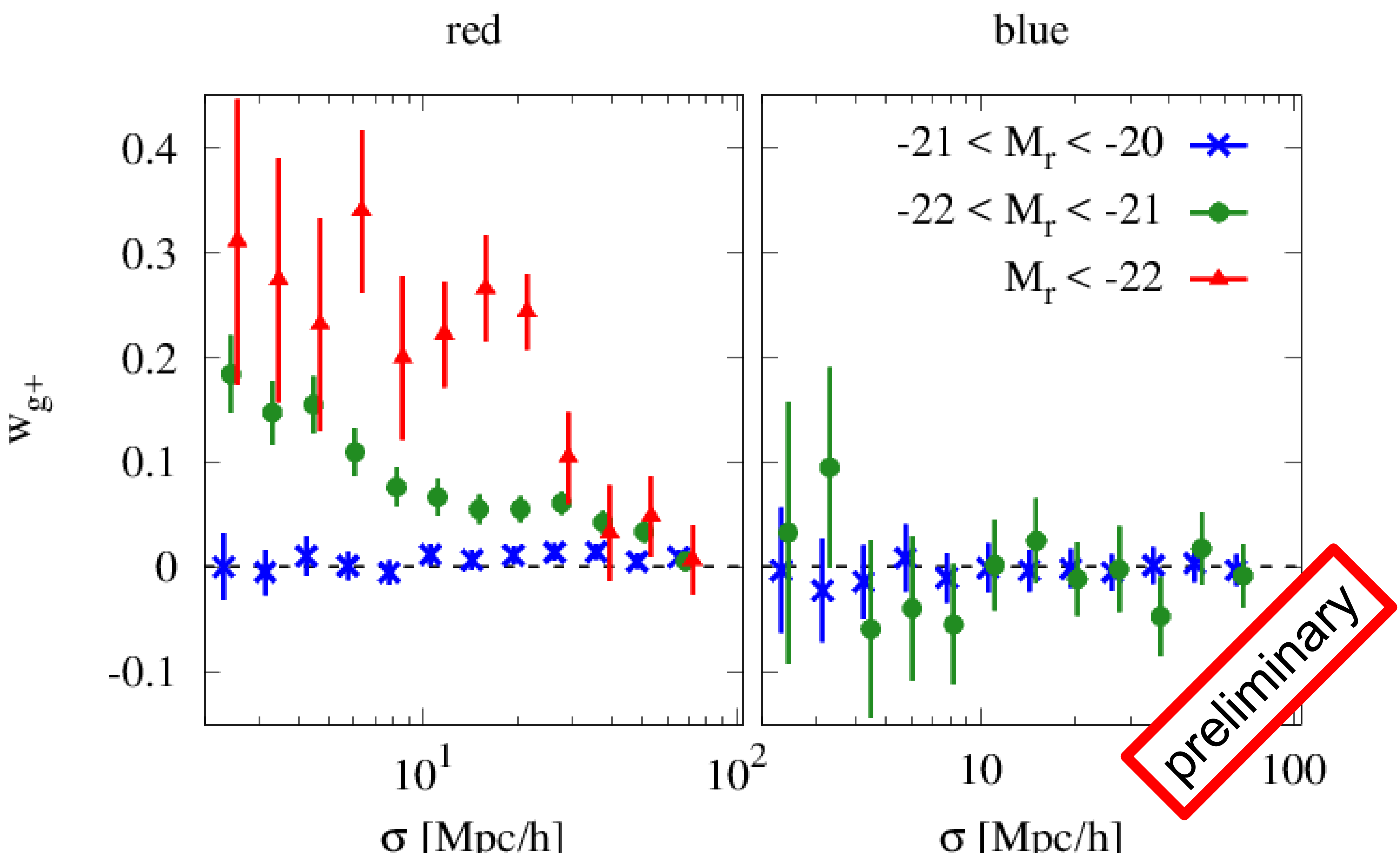


luminosity dependence of IA signal

bright → dim

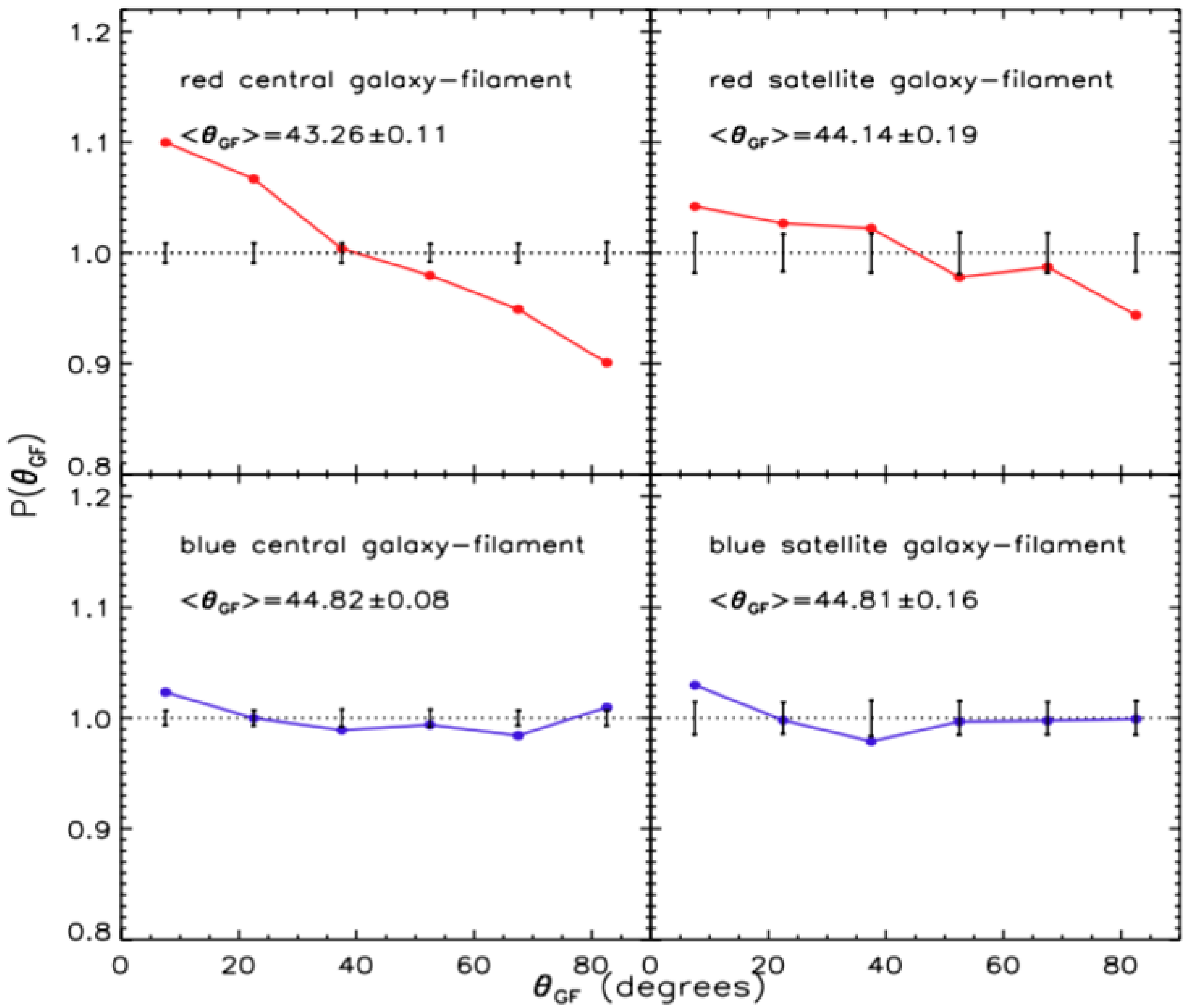


color dependence of IA signal



literature results on blue galaxy IA

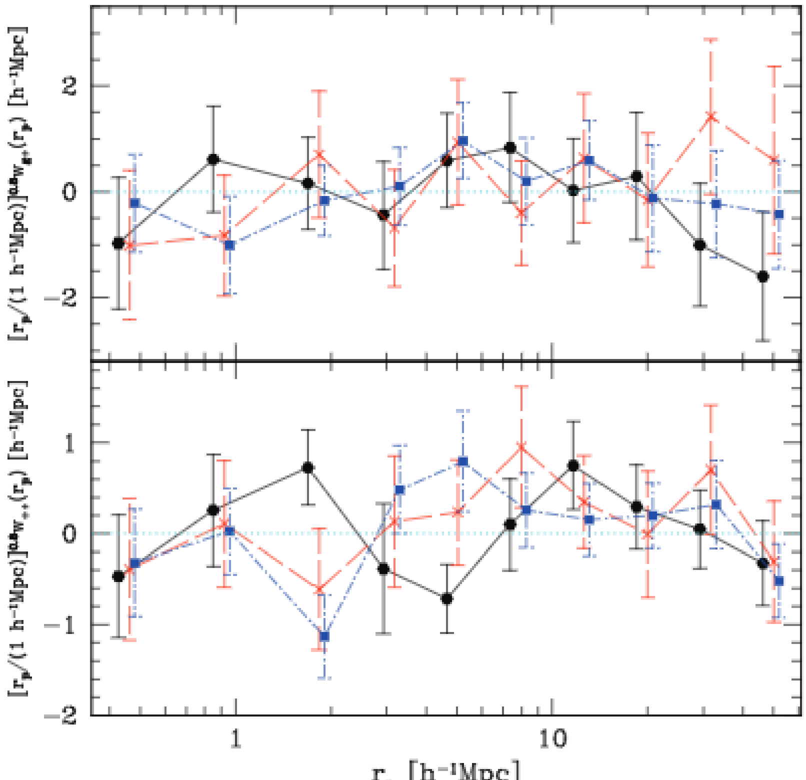
SDSS DR7 (Zangh et al. 2016)



$z \approx 0.1$

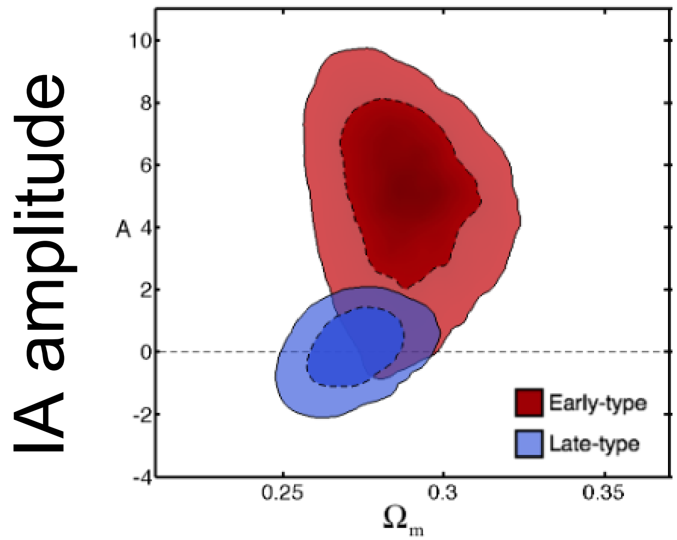
literature results on blue galaxy IA

WiggleZ
(Mandelbaum et al. 2011)



$z \approx 0.7$

CFHTLenS
(Heynmans et al. 2013)



-> no alignment of blue galaxies detected in observations

summary and ongoing work

- mimic intrinsic alignment of BOSS LRGs with simple toy model imposed on HOD+HAM galaxy catalogue from large N-body simulation

- model reproduces observed 2pt alignment statistics for different luminosities and colors on large scale range

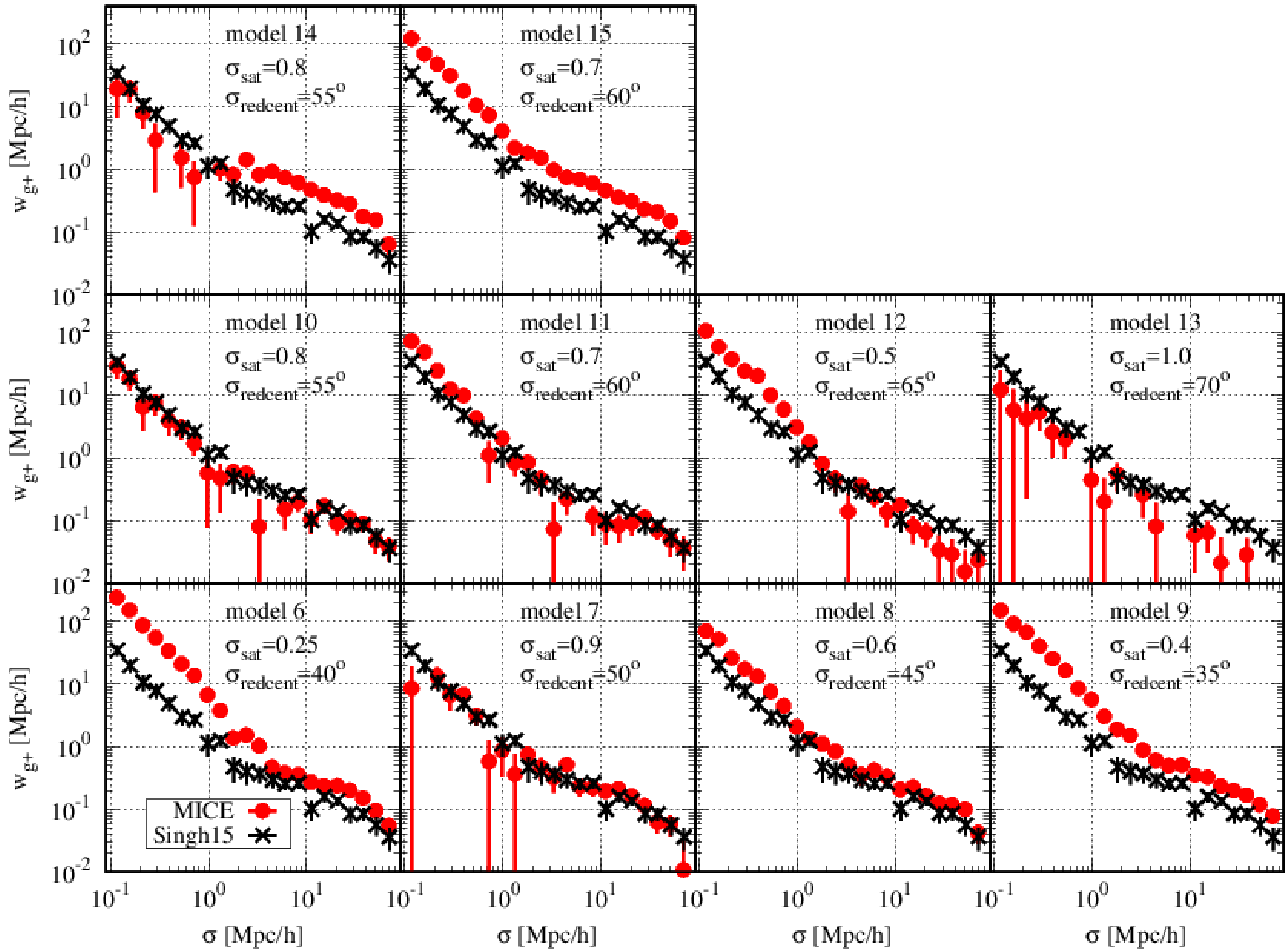
- toy model currently prepared for generating mock catalogues of dark energy surveys (now Euclid, later DES, PAU)

The

End …?

varying IA model parameters

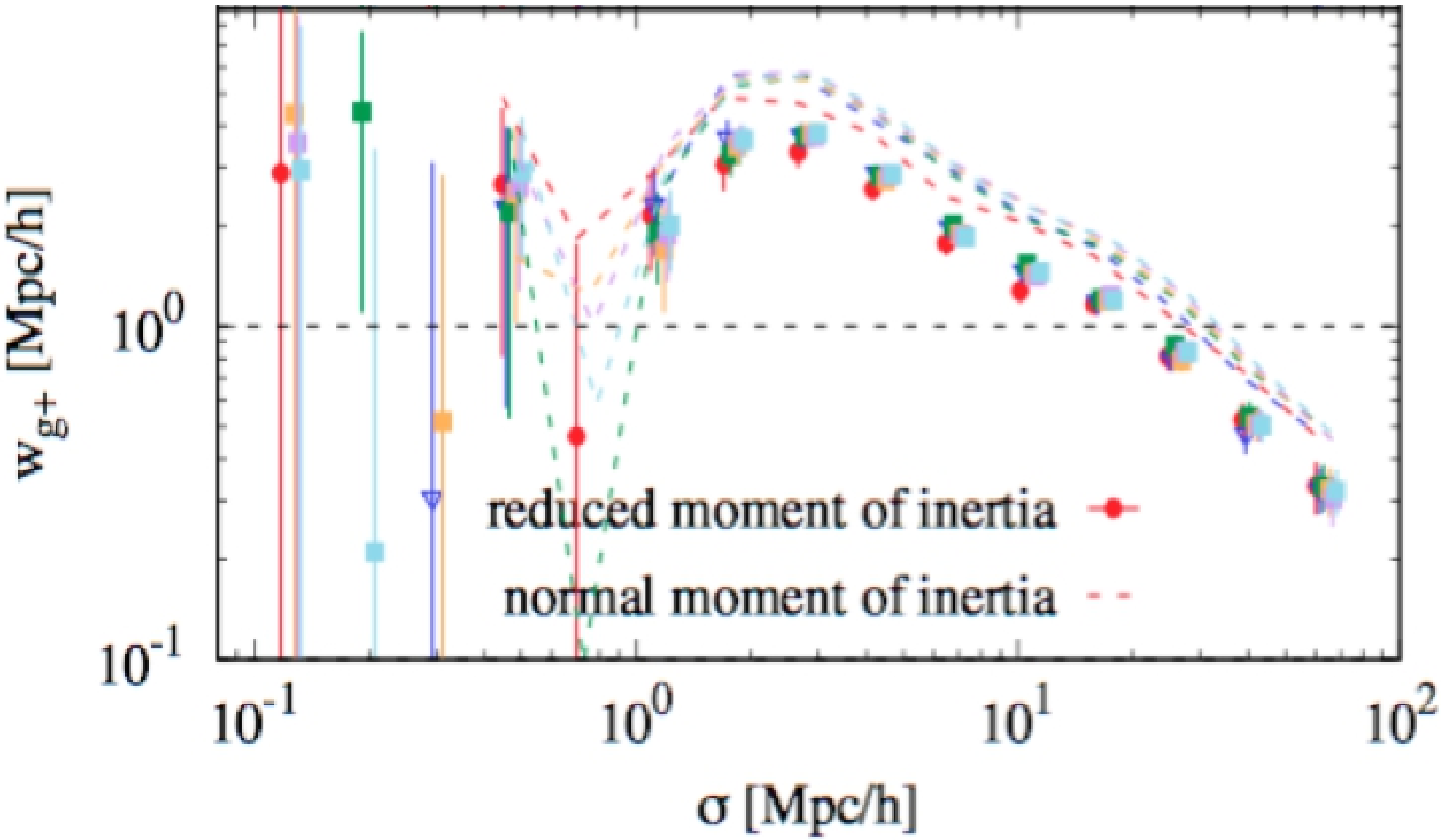
projected galaxy-shear correlation in BOSS LOWZ sample



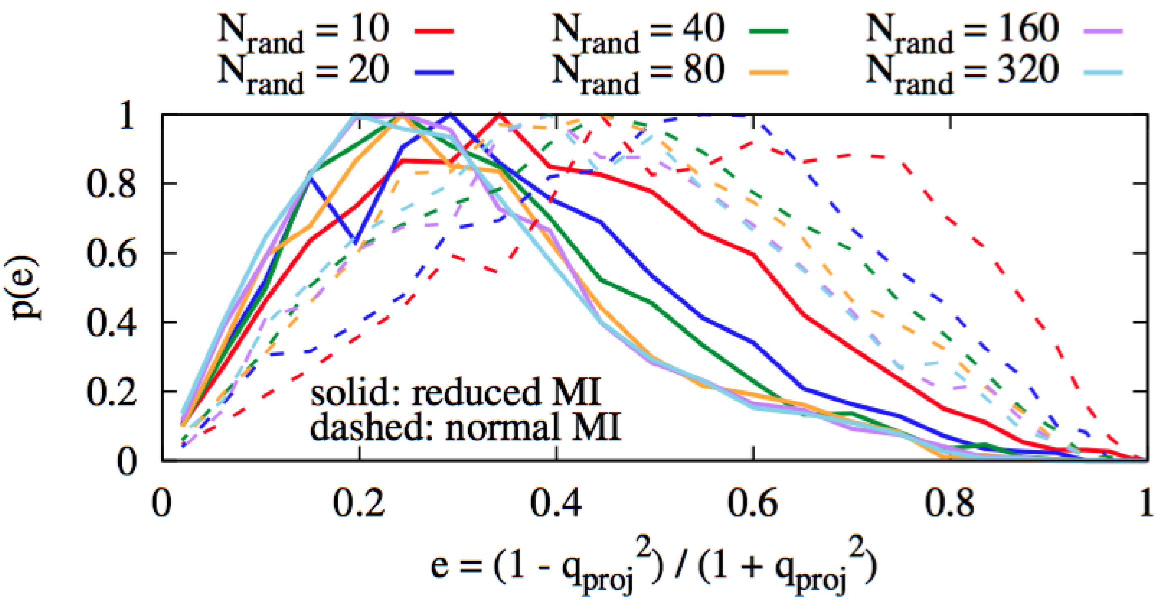
resolution test for shear correlation

- select halos with >320 particles
- subsample halos with 10, 20, 30, ..., 320 particles
- test how observables change

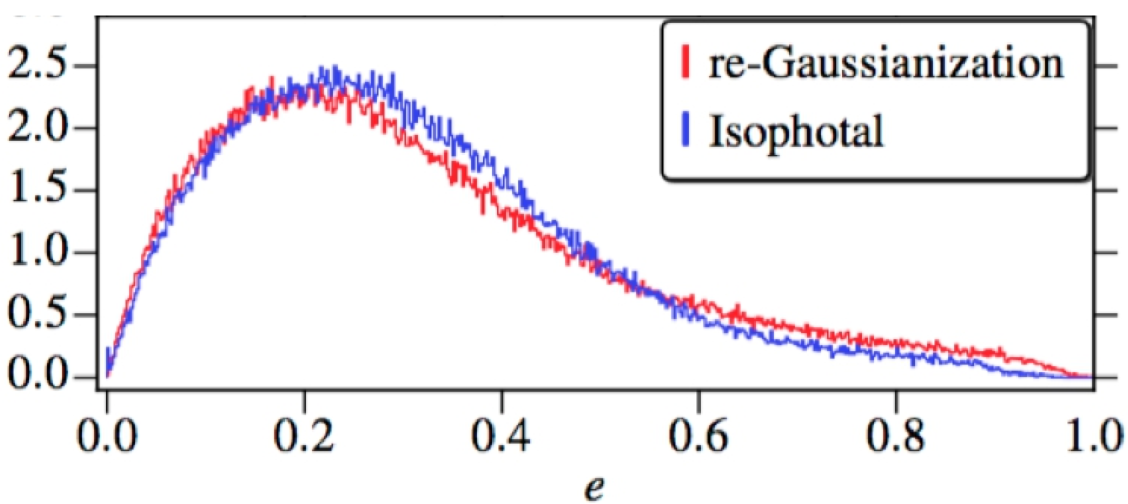
projected halo- shear correlation



ellipticity PDF

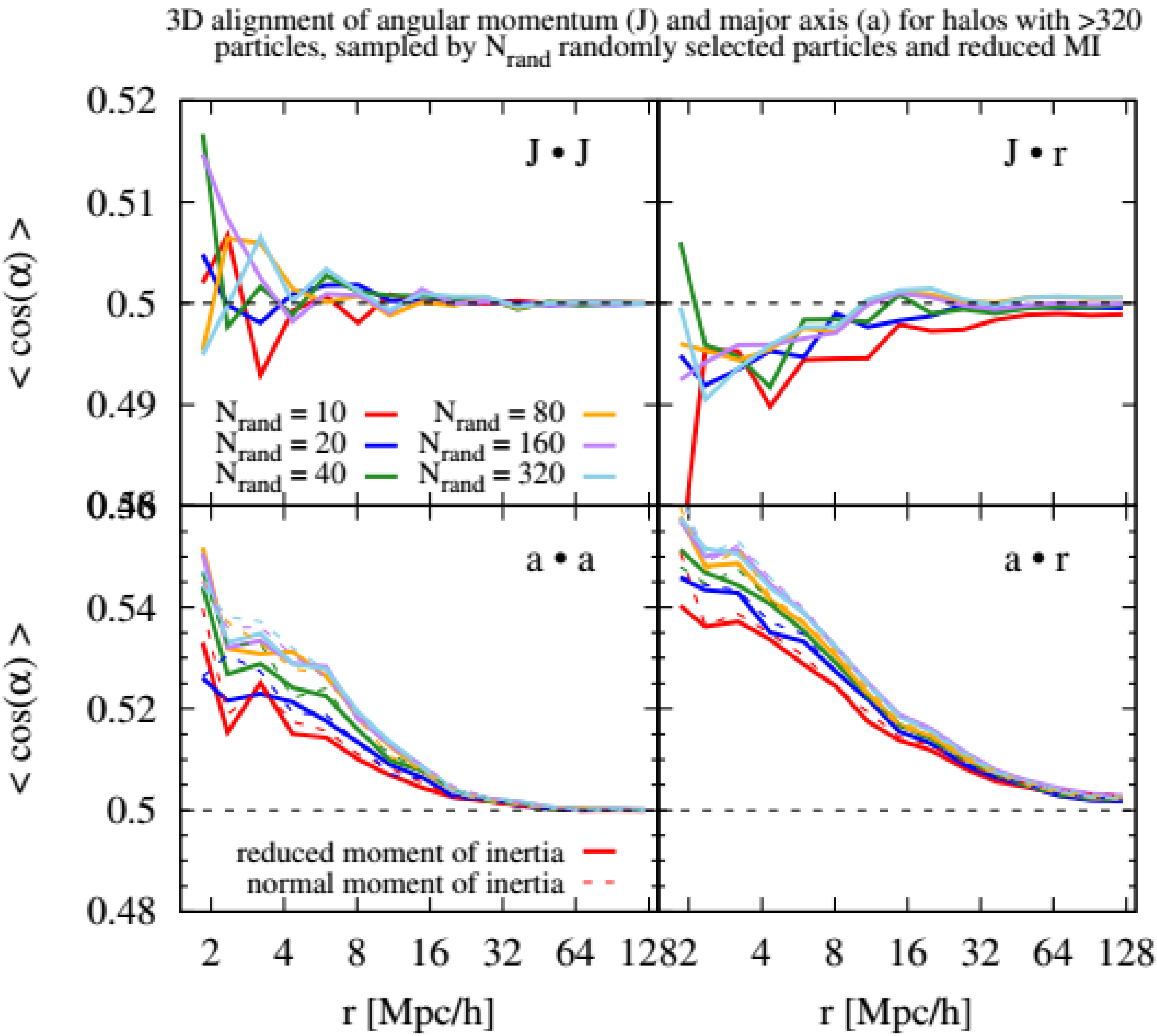


MICE-GC halos



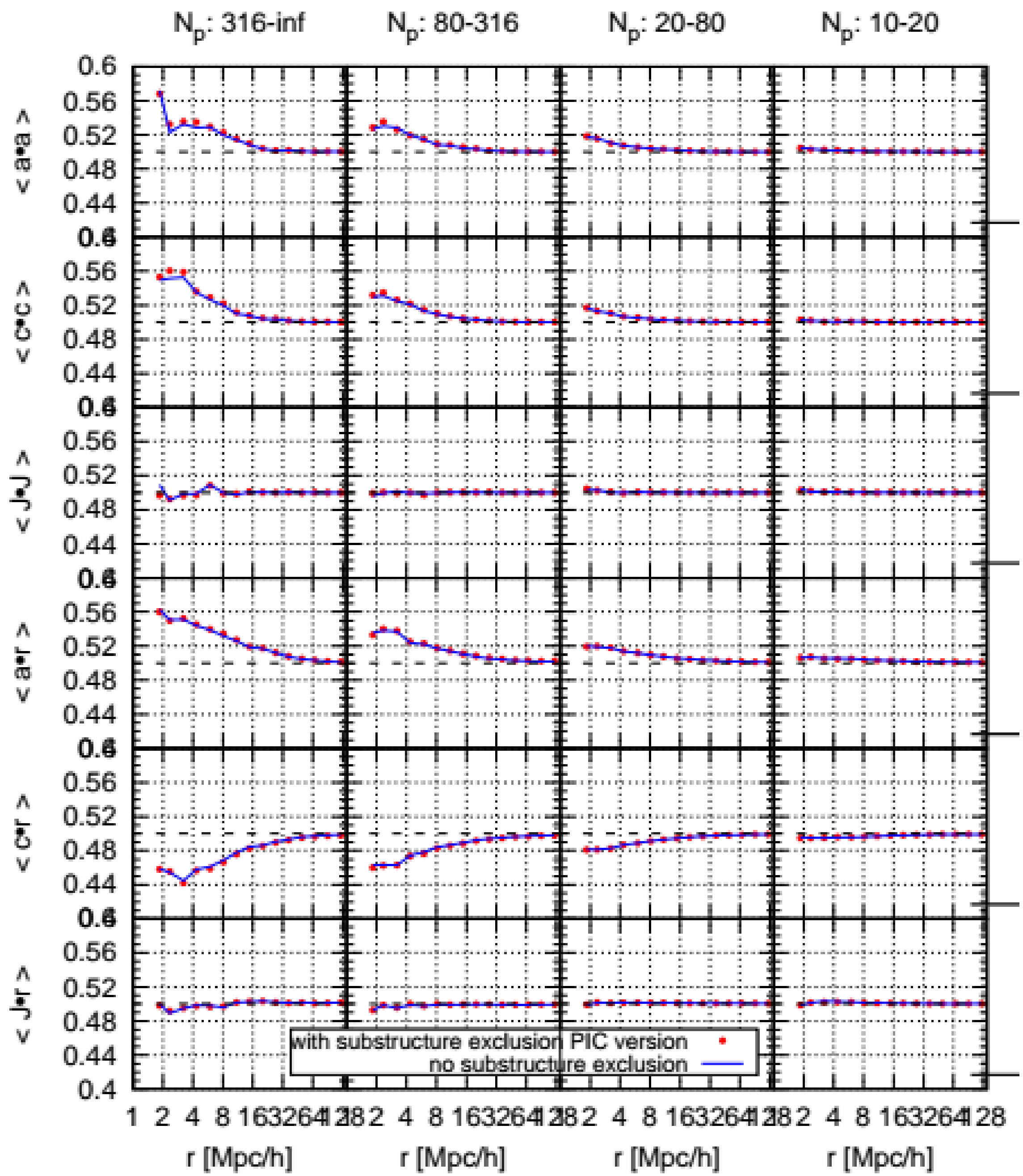
BOSS LOWZ LRGs (Singh, Mandelbam 2016)

3D halo alignment



- measurement depends only on halo orientations (not shapes)
- no clear difference between alignment signal from reduced (solid) and normal MI (dashed)

3D halo alignment

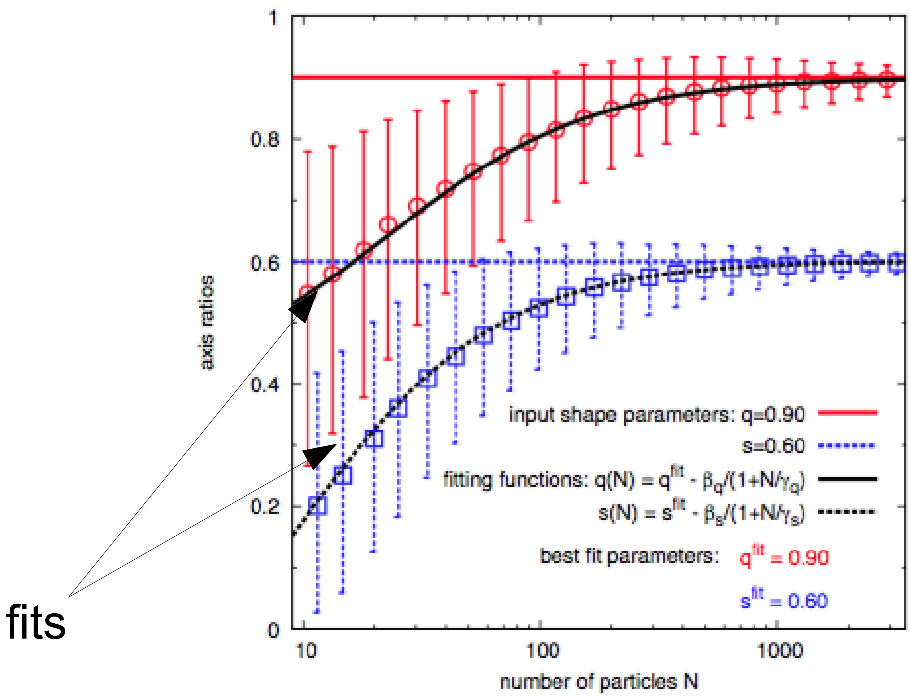


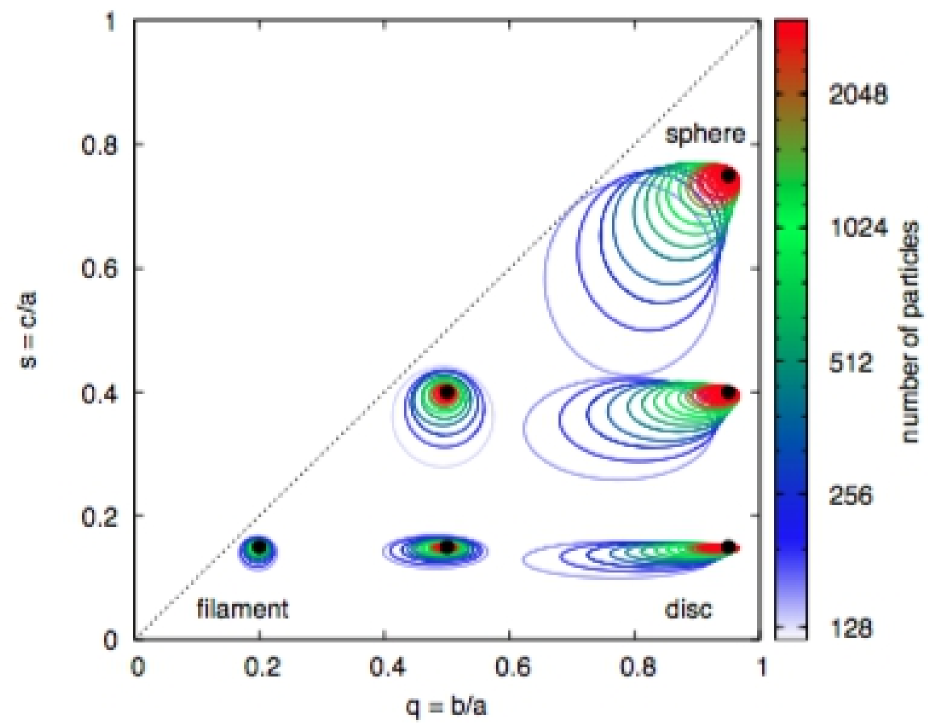
no clear difference between alignment of halos

- with substructure and
- without substructure

shapes are biased by low N_{part}

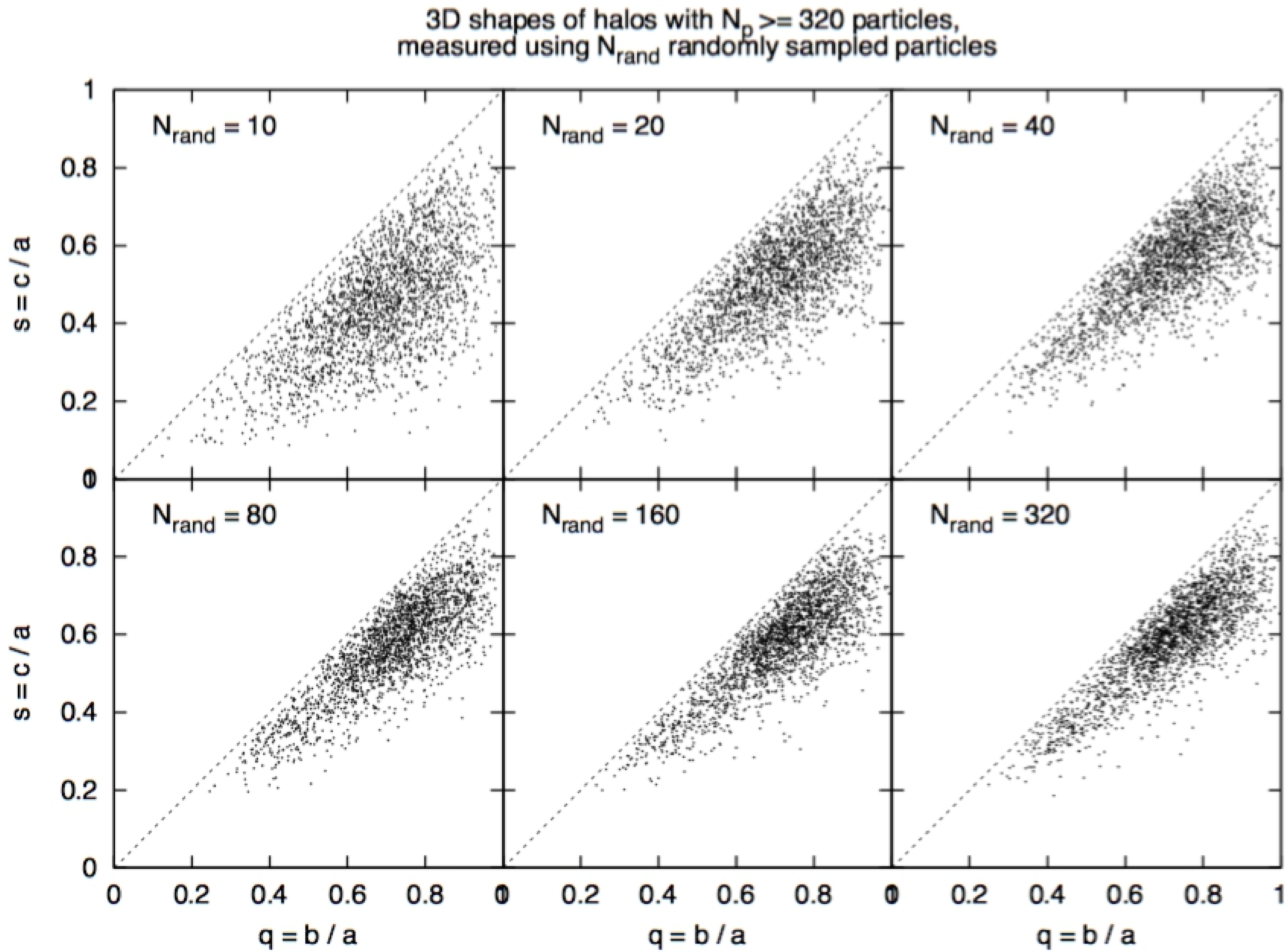
tests with artificial haloes
(Hoffmann et al. 2014, arXiv:1401.2060):



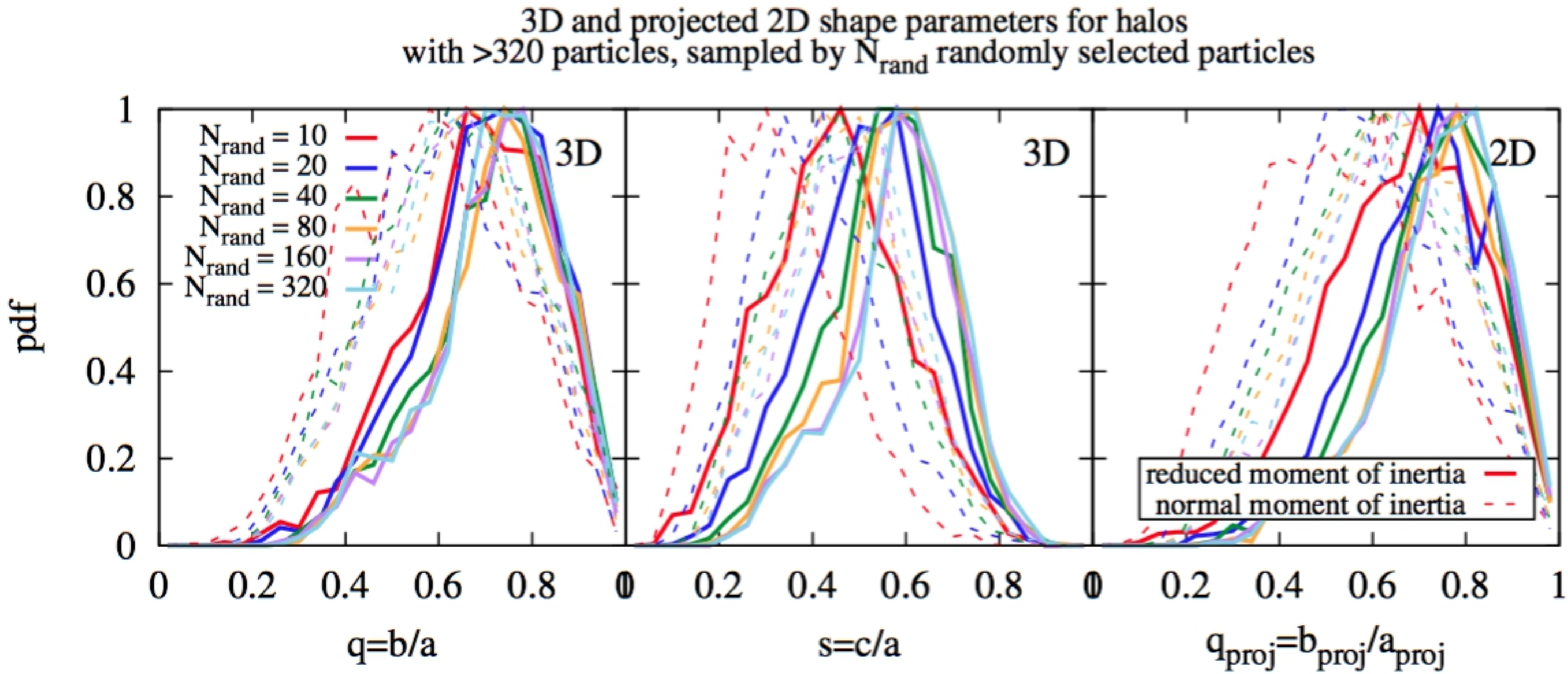


- Np_min > 1000 for 10% accuracy in 3D shapes!
- Joachimi use n > 300 <=> 8 10^{12} M_{sun} / h in MICE
- less particle needed for projected shapes?

shapes are biased towards triaxiality

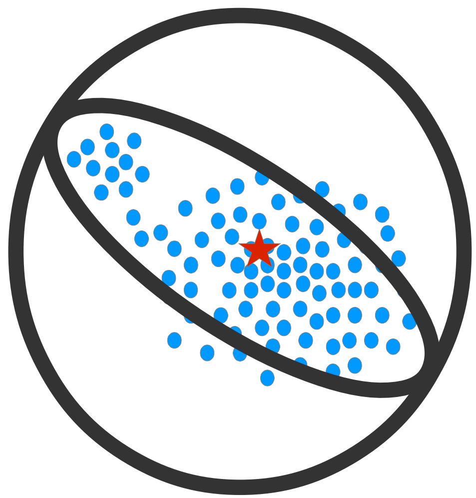


PDF of MICE halo shape parameters

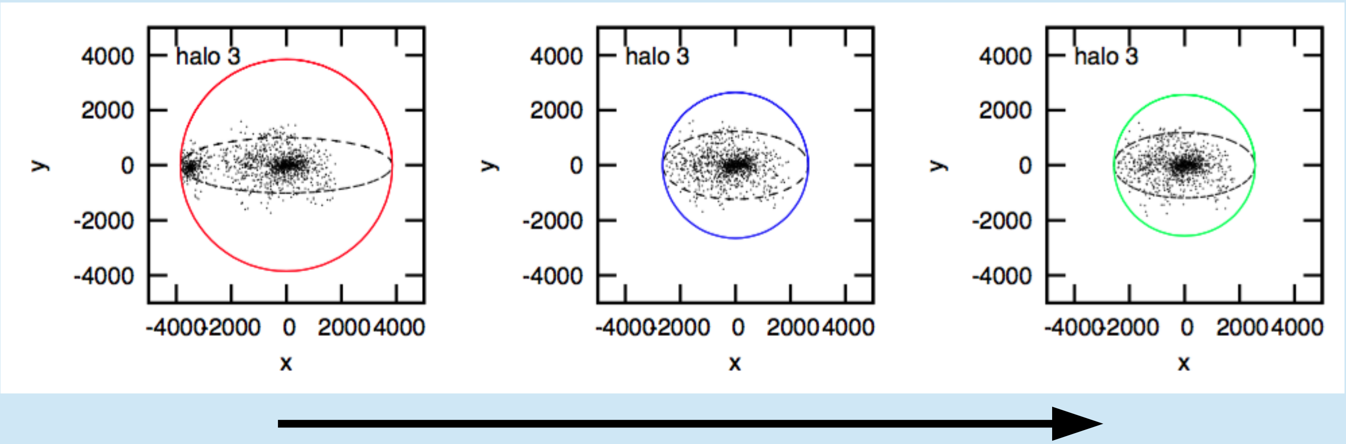


- triaxiality is higher (q&s are smaller) when
  - halos are sampled by low numbers of particles
  - shape parameters are derived from normal MI
- stronger resolution dependence for normal MI

shapes are biased by substructure

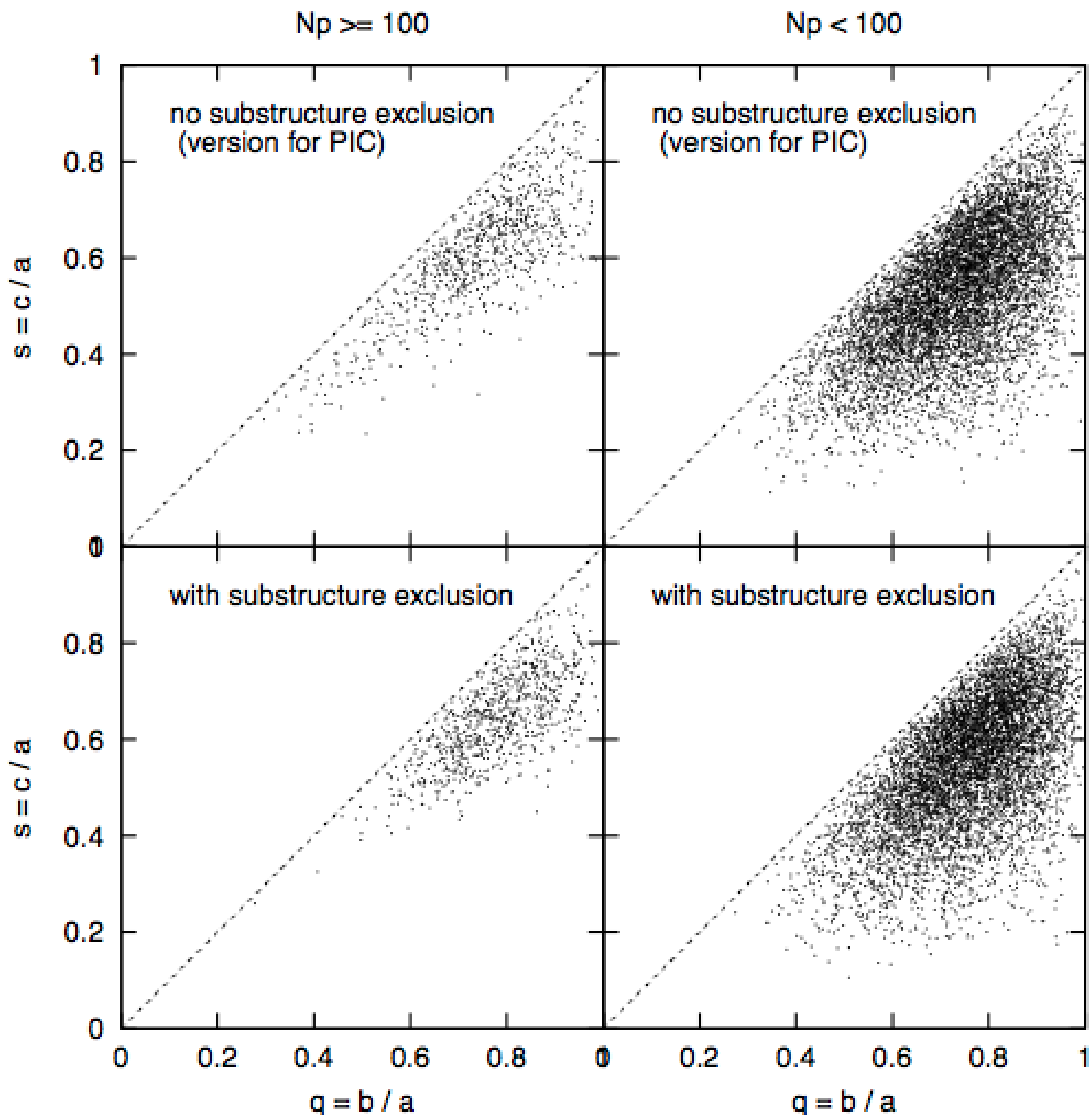


procedure for excluding substructure

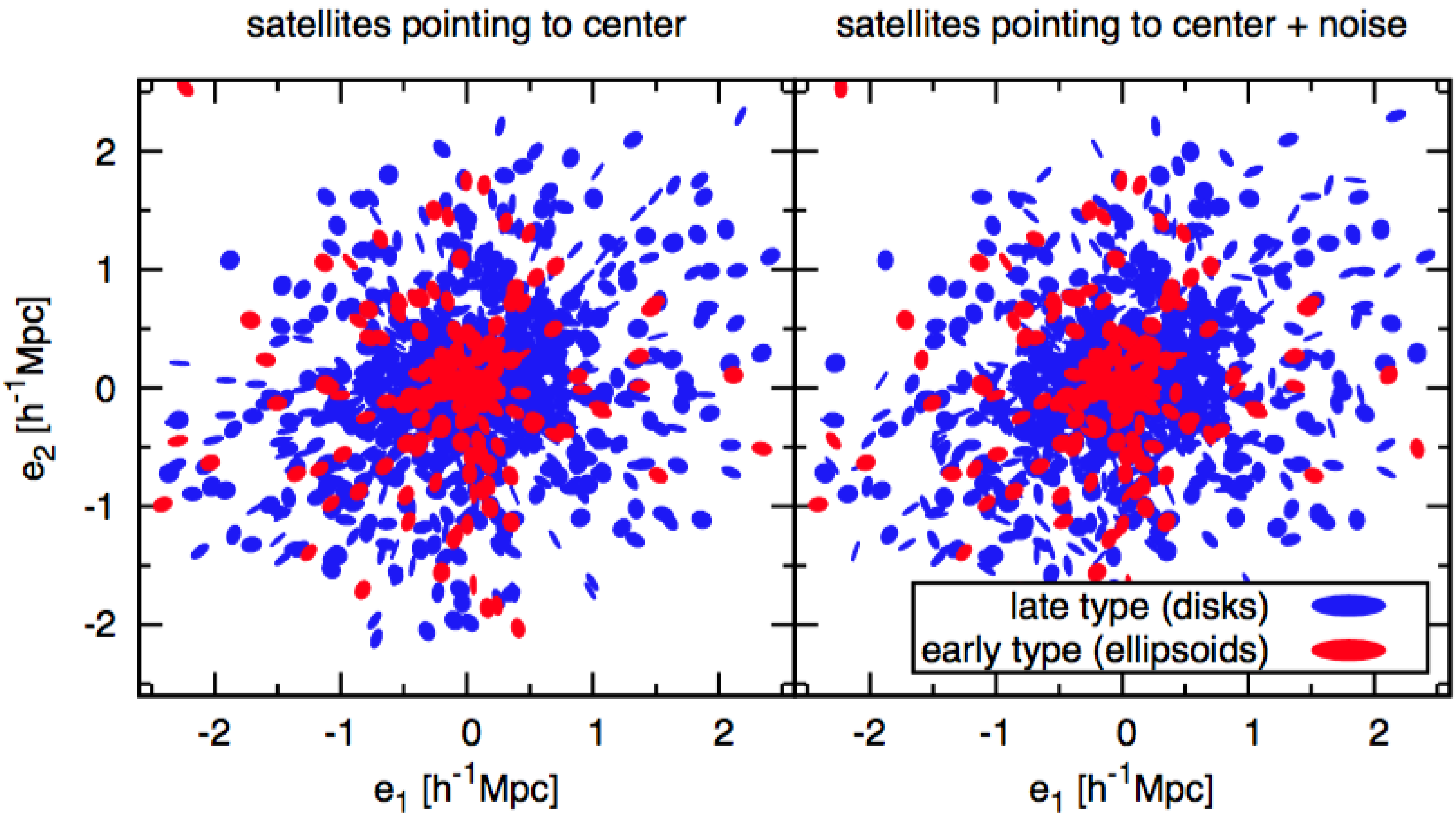


- not applied in current analysis
- better done by Rockstar, AHF etc. anyway..

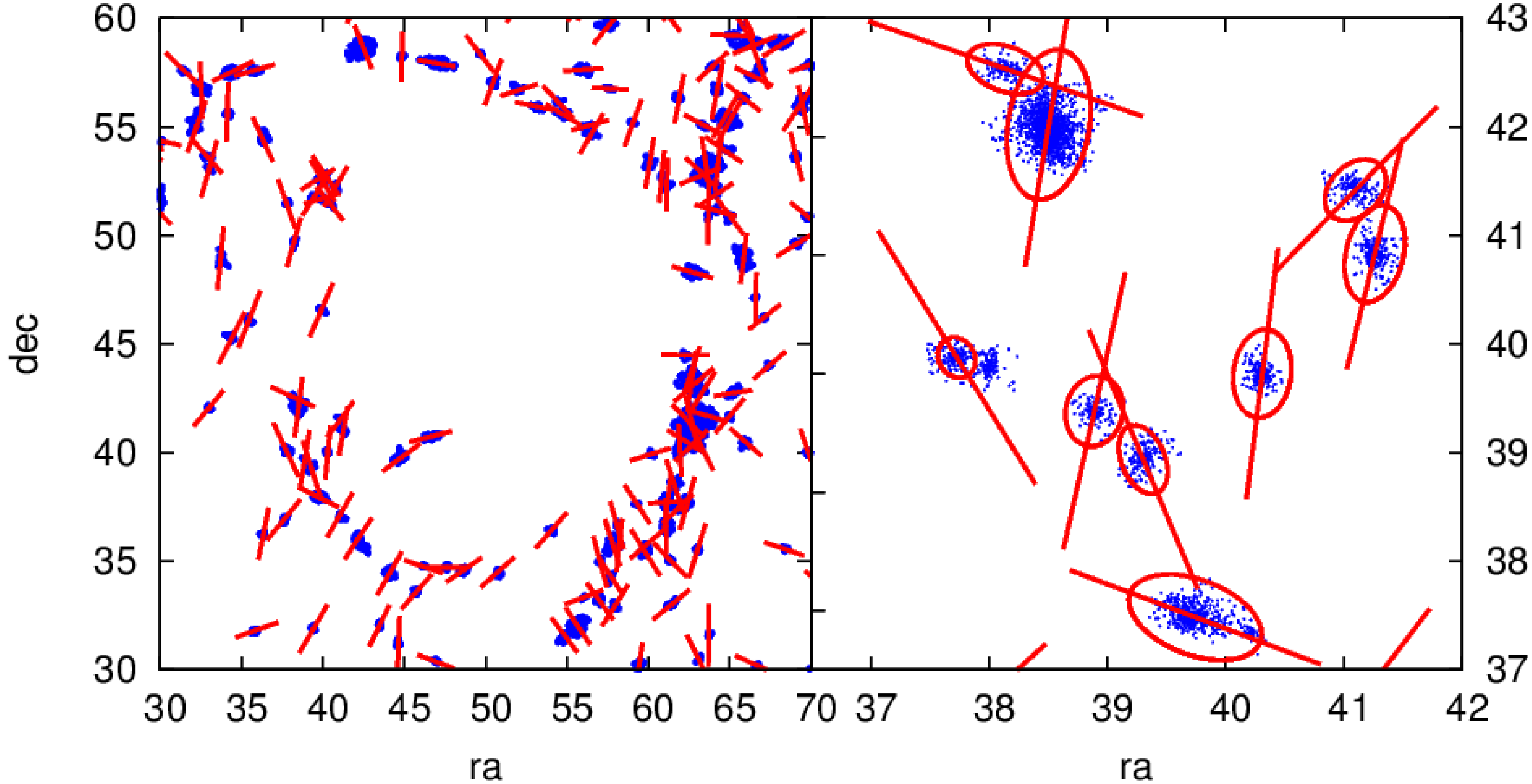
hallo shapes in MICE-GC



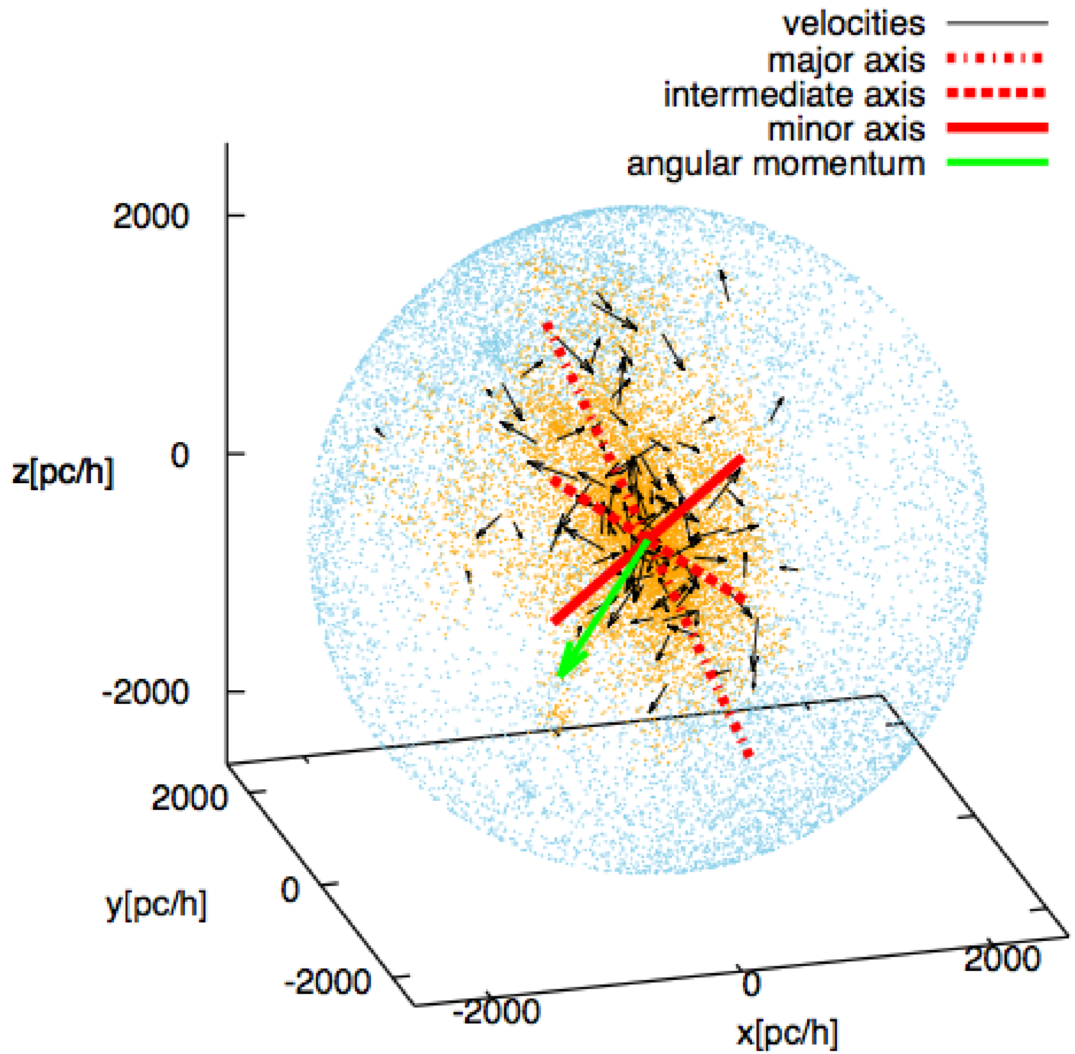
modeling intrinsic miss alignment



halo alignment



reduced moment of inertia



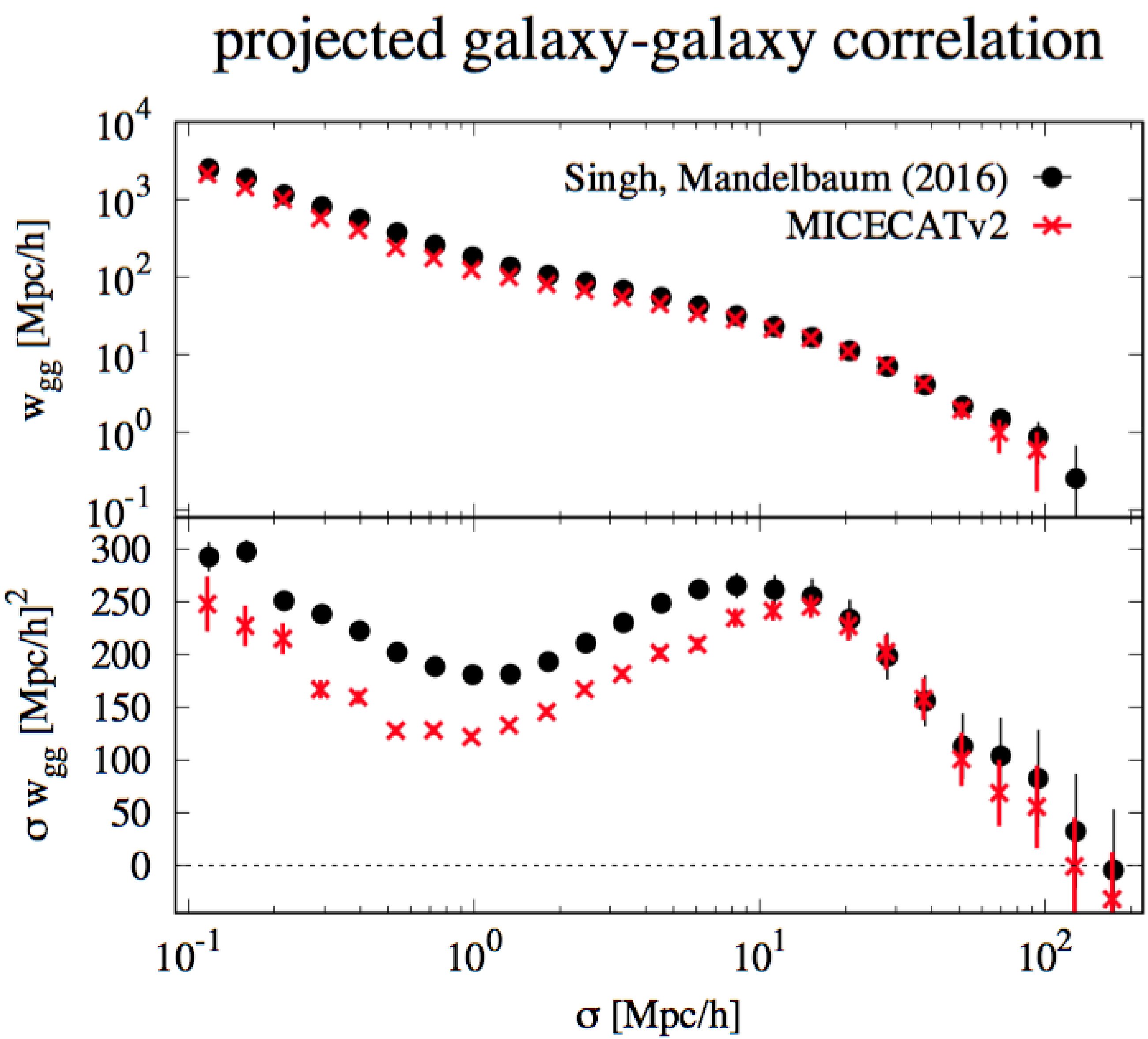
HOD galaxy assignment

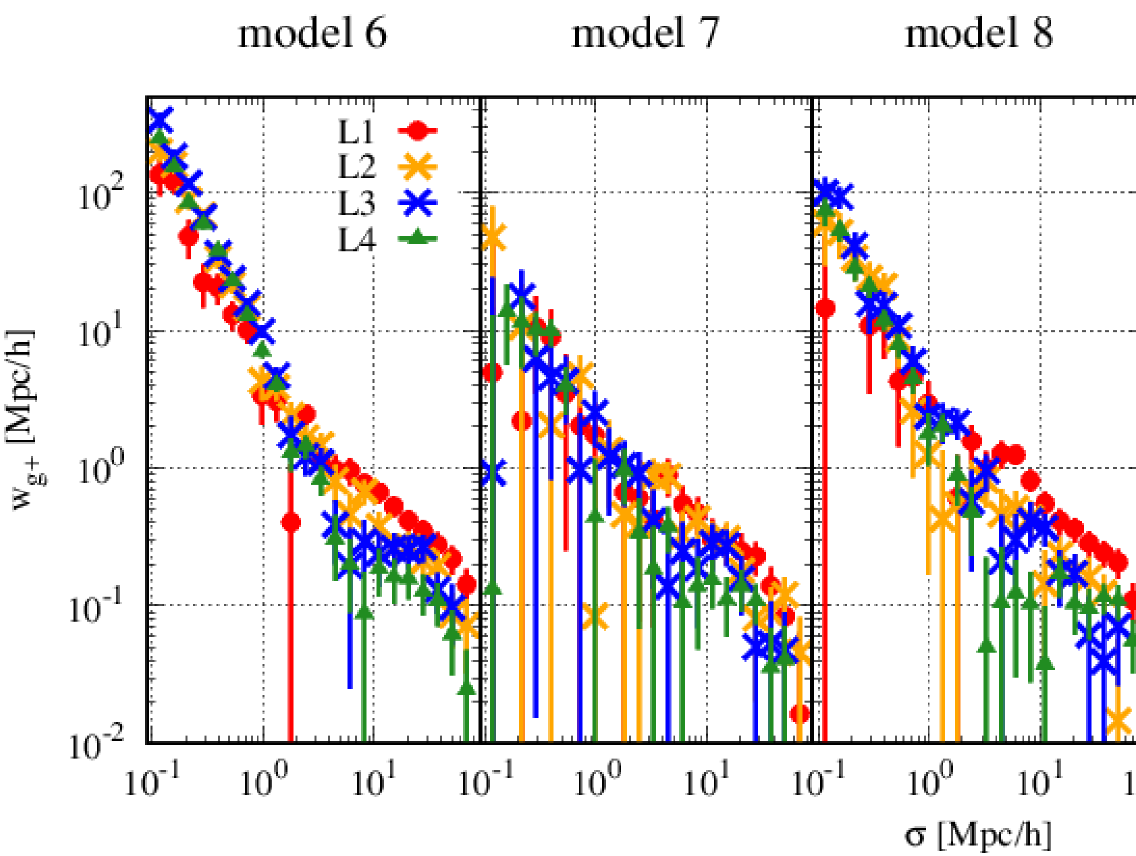
Luminosity We populate halos with one central and maybe some satellite galaxies (HOD) $\langle N_{sat} \rangle = (M/M_1)^{\alpha}$
Luminosities set to match the r - band luminosity of SDSS

Color We assign (g-r) color using the color bi-modality at fixed M_r

Clustering We place centrals at the halo centers and satellites following an NFW profile with bulk + virial velocity decomposition.
Tune HOD by computing projected correlation function as a function of color and magnitude and comparing with observations.

*slide from Pablo Fossalba


projected galaxy-galaxy correlation
Singh, Mandelbaum (2016)
MICECATv2
w_{gg} [Mpc/h]
$\sigma\, w_{gg}$ [Mpc/h]^2
σ [Mpc/h]
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
10^{4}
300
250
200
150
100
50
0



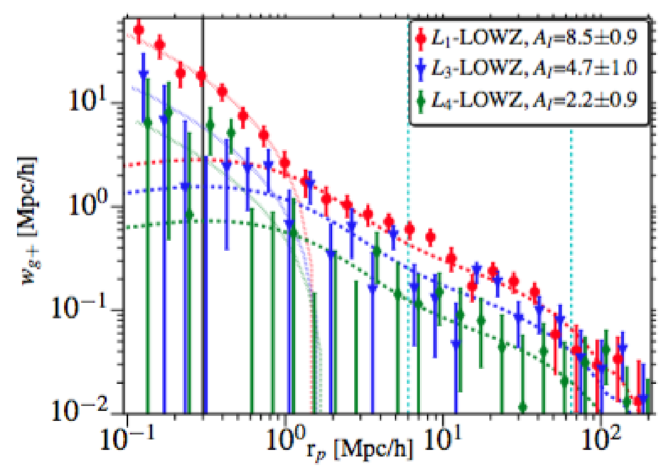


Figure 9. Density-shape correlation functions for samples defined using luminosity cuts, L_1, L_3, L_4 samples, as specified in Table 2. $L_1 - L_4$ are arranged in order of luminosity, with L_1 being brightest and L_4 being faintest. The L_2 sample is not shown in the figure for clarity. Brighter galaxies have higher intrinsic alignments amplitude, with luminosity trend of A_I being well described by a power law (Eq. 34).

fitting IA models