Intrinsic Alignments using Smoothed Particle Hydrodynamic Simulations

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Intrinsic Alignments using Smoothed Particle Hydrodynamic Simulations

Results from :

> Shapes and alignments of dark matter and stellar matter of subhalos using cosmological hydrodynamic simulations (draft in preperation)

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Overview

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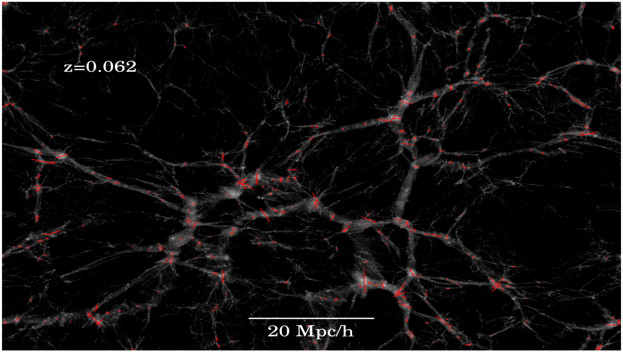
MassiveBlack-II Simulation

- High resolution SPH simulation : cubic periodic box of size $100h^{-1}Mpc$
- Mass of each dark matter particle : $1.1 \times 10^7 h^{-1} M_\odot$
- Total Number of dark matter particles : 5.75×10^9
- Cosmology : according to *WMAP7*
- Physics : Gravity, hydrodynamics, star formation, black hole accretion and feedback

More details can be found in “Khandai et al. 2013” (in prep)

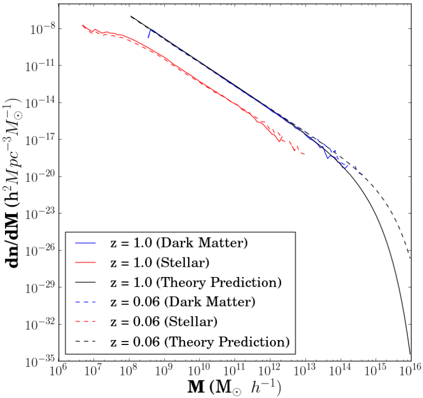
Snapshot of MB-II : Large Scale Structure



- A slice of thickness $2h^{-1}Mpc$ at redshift $z = 0.06$ showing the distribution of Dark Matter (shown in grey) and alignments of Stellar shapes (shown in red lines)

Halo and Stellar Mass Function

Group, Subgroup catalogs : generated using FoF group finder and SUBFIND algorithm (Springel et. al 2001)



Mass function compared with theoretical prediction in “Tinker et. al 2008”

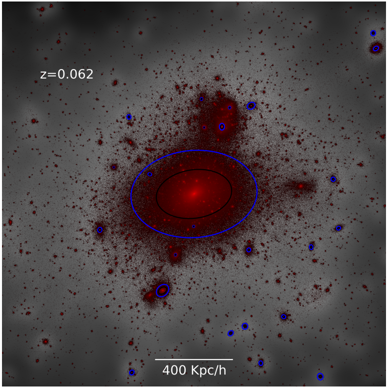
Modelling Dark Matter and Stellar shapes as ellipsoids in 3d

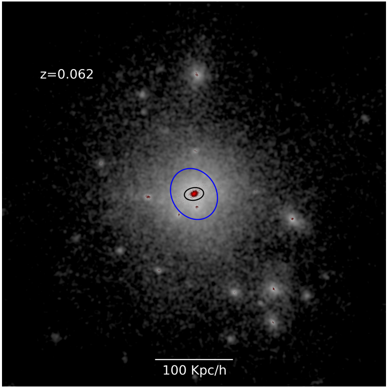
- Unweighted Inertia Tensor using all particles in a halo or subhalo

$$I_{ij} = \frac{\sum_n m_n x_{ni} x_{nj}}{\sum_n m_n}, \tag{1}$$

- m_n : mass of n^{th} particle
- x_{ni}, x_{nj} : position co-ordinates of n^{th} particle , $0 \leq i, j \leq 2$
- Eigenvectors of the inertia tensor, $\hat{e}_a, \hat{e}_b, \hat{e}_c$: principal axes of ellipsoids
- Lengths of principal axes : $a = \sqrt{\lambda_a}$, $b = \sqrt{\lambda_b}$, $c = \sqrt{\lambda_c}$, with $a \geq b \geq c$
- Axis Ratios : $q = \frac{b}{a}$, $s = \frac{c}{a}$

Zoomed snapshots of halos in MB-II at $z = 0.06$





Dark matter and stellar distribution at $z = 0.06$ in the most massive group of mass $7.2 \times 10^{14} M_{\odot} h^{-1}$ and a halo of mass $1.1 \times 10^{12} M_{\odot} h^{-1}$

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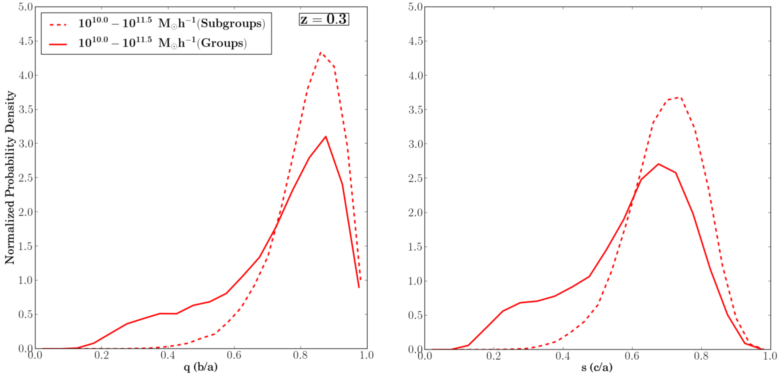
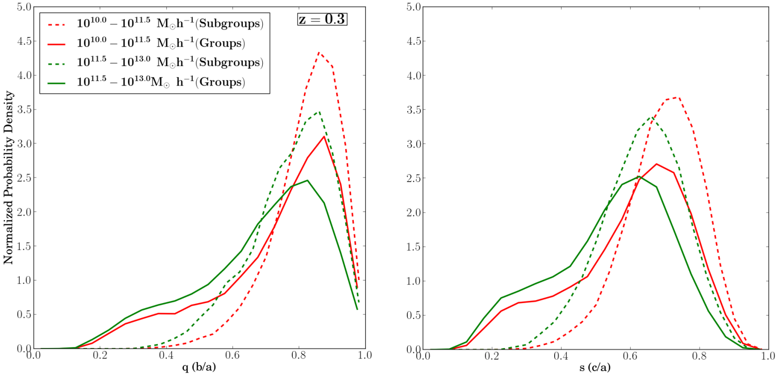
Groups and Subgroups: Dark matter



- Comparison of axis ratios, $q(b/a)$ and $s(c/a)$ between dark matter subgroups and groups at $z = 0.3$
- Subgroups are more round than groups of similar mass
- Decreasing axis ratios with increasing mass of groups and subgroups

Groups and Subgroups: Dark matter



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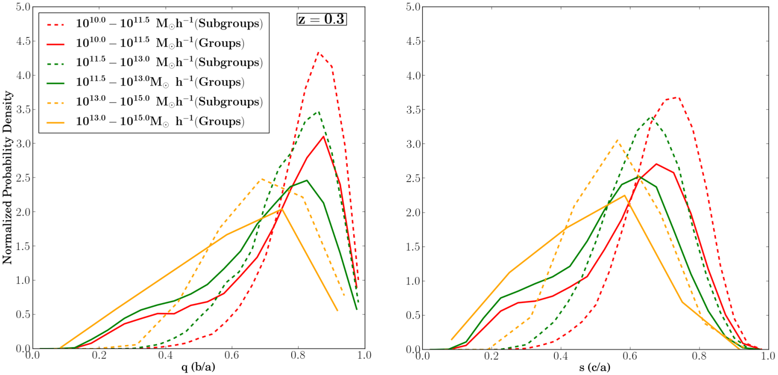

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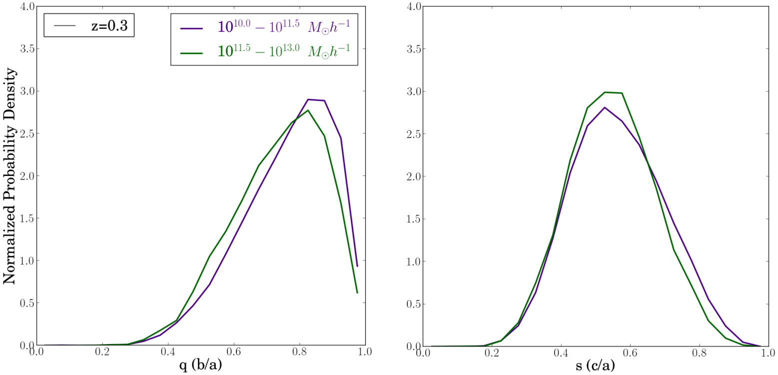
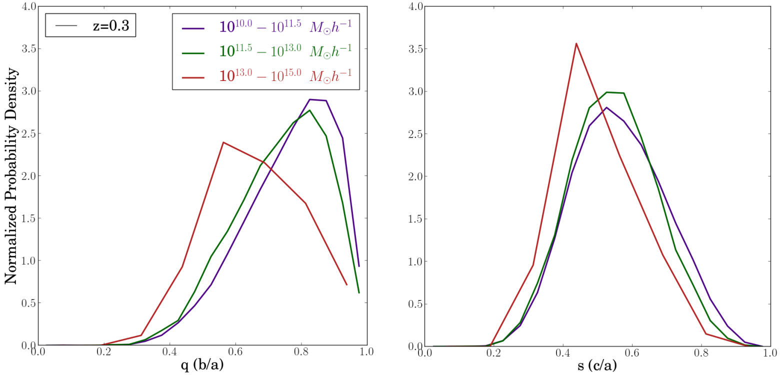
Stellar Shapes : Mass dependance



- Axis ratios, $q(b/a)$ and $s(c/a)$ for stellar matter of subhalos at $z = 0.3$
- Axis ratios are smaller in higher mass bins

Stellar Shapes : Mass dependance



- Axis ratios, $q(b/a)$ and $s(c/a)$ for stellar matter of subhalos at $z = 0.3$
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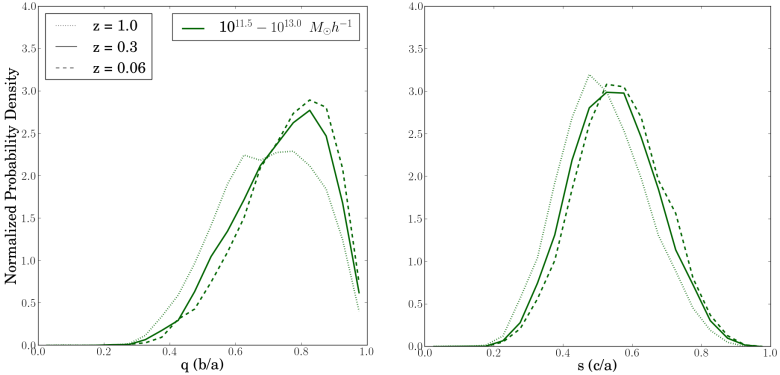
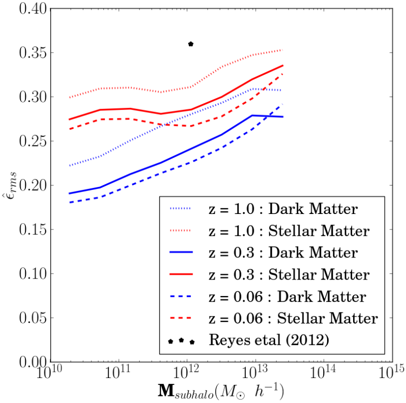
Stellar Shapes : Redshift evolution



- Axis ratios, $q(b/a)$ and $s(c/a)$ for stellar matter of subhalos at $z = 1.0, 0.3, 0.06$
- Axis ratios are larger at lower redhsifts

RMS ellipticity ($\hat{\epsilon}_{rms}$)



- RMS ellipticity per component,

$$\hat{\epsilon}^2_{rms} \equiv \frac{\sum_i \left(\frac{1-q_i^2}{1+q_i^2}\right)^2}{2N}, \qquad (2)$$

$$q_i = \frac{b_i}{a_i}, \text{ for } i^{th} \text{ subgroup}$$

- $\hat{\epsilon}_{rms} = 0.28$ at $z = 0.3$ for $M_{subhalo} > 10^{12} M_\odot h^{-1}$
- Dark matter shapes are more round than stellar shapes

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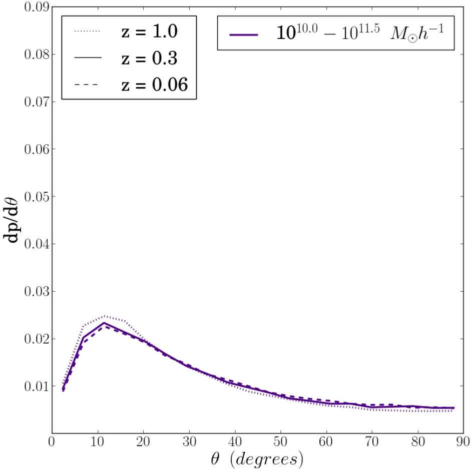
Misalignments in 3d : Mass dependance and redshift evolution

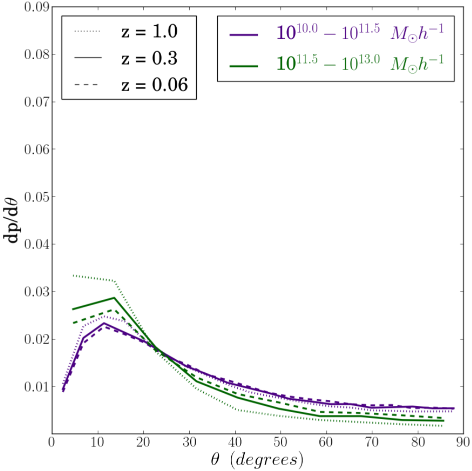


- $\hat{e}_{sa}$: Major axis of stellar component
- $\hat{e}_{da}$: Major axis of dark matter component
- Mislaignment angle (θ_m) given by

$$\theta_m = \arccos(\hat{e}_{sa} \cdot \hat{e}_{da}) \quad (3)$$

- Misalignment of stellar component with dark matter component is lower in massive bins

Misalignments in 3d : Mass dependance and redshift evolution



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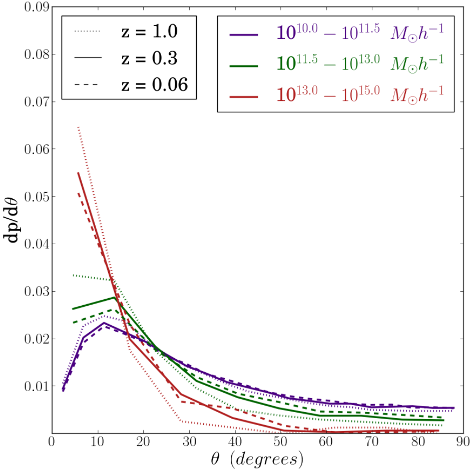


- $\hat{e}_{sa}$: Major axis of stellar component
- $\hat{e}_{da}$: Major axis of dark matter component
- Mislaignment angle (θ_m) given by

$$\theta_m = \arccos(\hat{e}_{sa} \cdot \hat{e}_{da}) \quad (5)$$

- Misalignment of stellar component with dark matter component is lower in massive bins

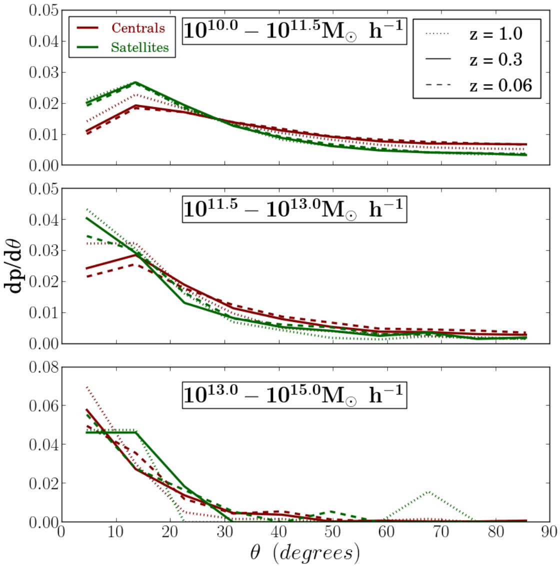
Mean misalignments in 3d

- Mean 3d misalignments in subgroups

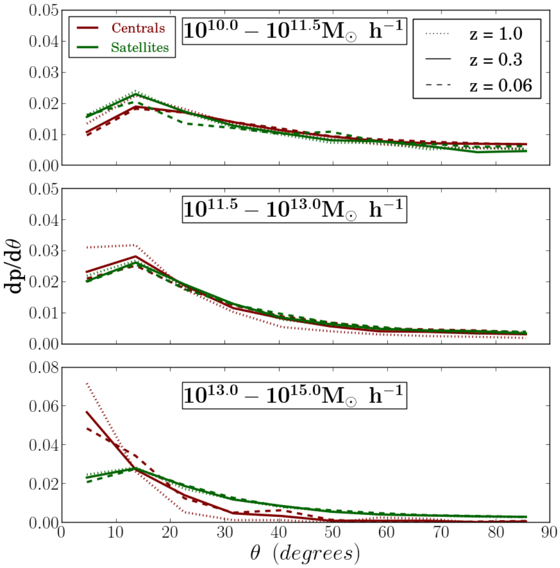
Mass($M_\odot h^{-1}$)	$z = 1.0$	$z = 0.3$	$z = 0.06$
$10^{10.0} - 10^{11.5}$	31.61°	33.47°	34.10°
$10^{11.5} - 10^{13.0}$	20.98°	25.20°	27.73°
$10^{13.0} - 10^{15.0}$	10.00°	13.04°	13.87°

- For a given redshift, mean misalignment is smaller in higher mass bins
- For a given massbin, mean misalignment is larger at lower redshifts

Subhalo Mass bins



Halo Mass bins



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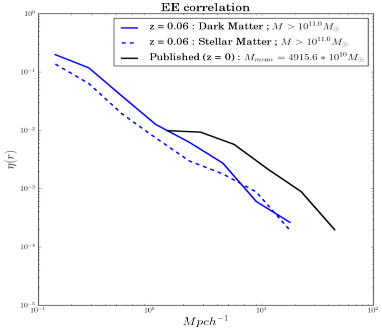
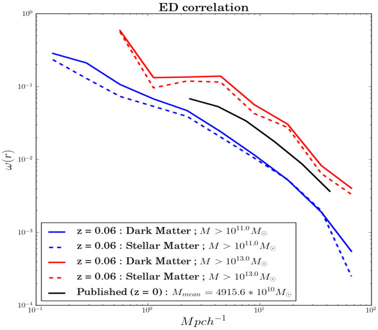
EE, ED correlation function in $3d$





- EE correlation, $\eta(r) = \langle |\ \hat{e}(x) \cdot \hat{e}(x+r)\ |^2 \rangle - \frac{1}{3}$
- ED correlation, $\omega(r) = \langle |\ \hat{e}(x) \cdot \hat{\mathbf{r}}(x)\ |^2 \rangle - \frac{1}{3}$
- Comparison with calculations in “Lee et. al 2008”

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Summary

- Use of SPH simulations to investigate the shapes and relative orientations of dark matter and stellar matter of subhalos
- Dark matter shapes of subhalos have higher axis ratios than stellar matter subhalos
- Axis ratios of dark matter and stellar matter are higher in subhalos of lower mass
- Axis ratios increase as we got lower redshifts
- Measurement of misalignment angles between the dark matter and stellar matter component of subhalos
- Misalignments are larger in subhalos of low mass and increase as we go to low redshifts
- Misalignments in Satellite subgroups are larger than Central subgroups of similar mass.
- Future work : Investigation of two point correlation functions and comparison with real data

Thank You