Halo Model

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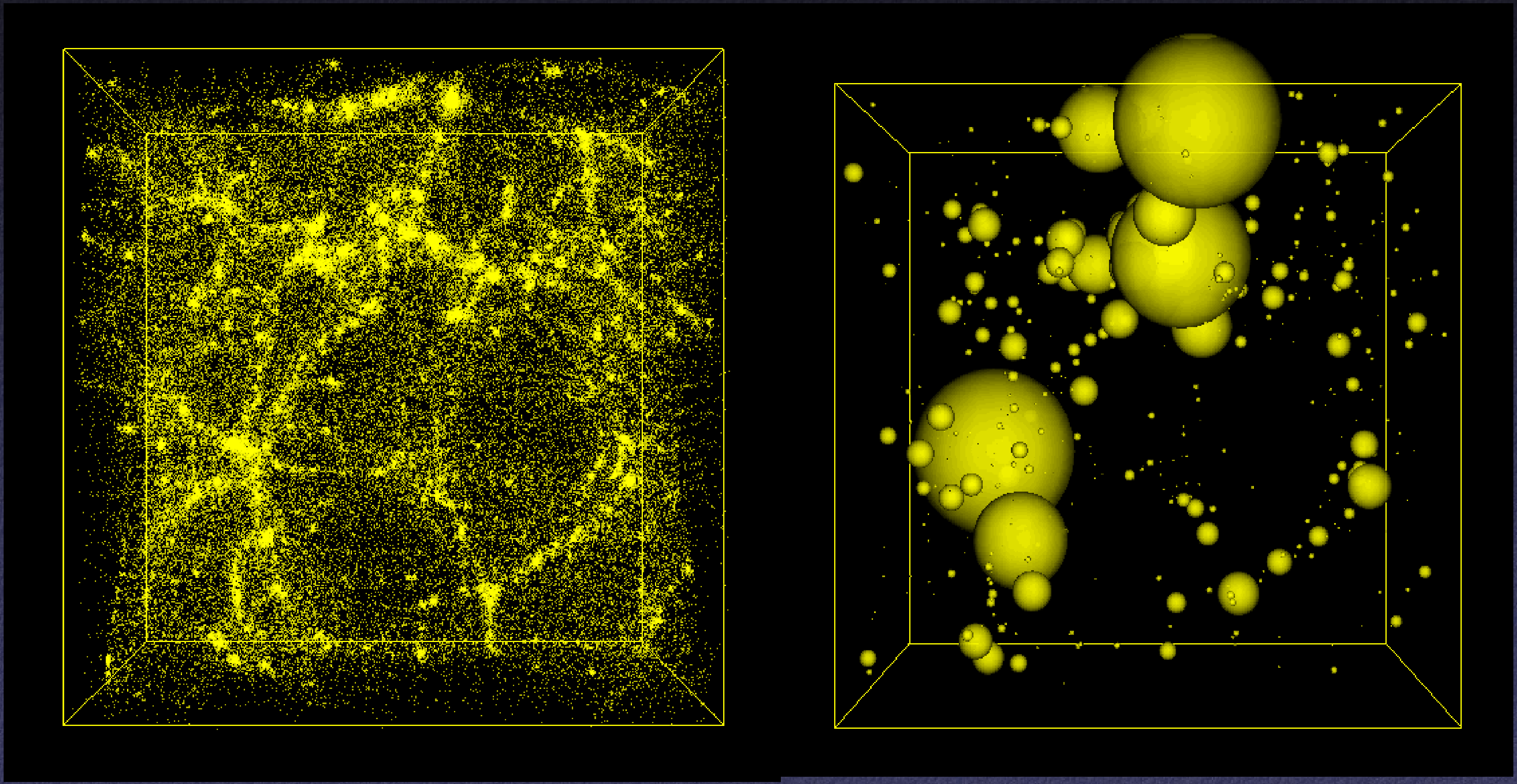
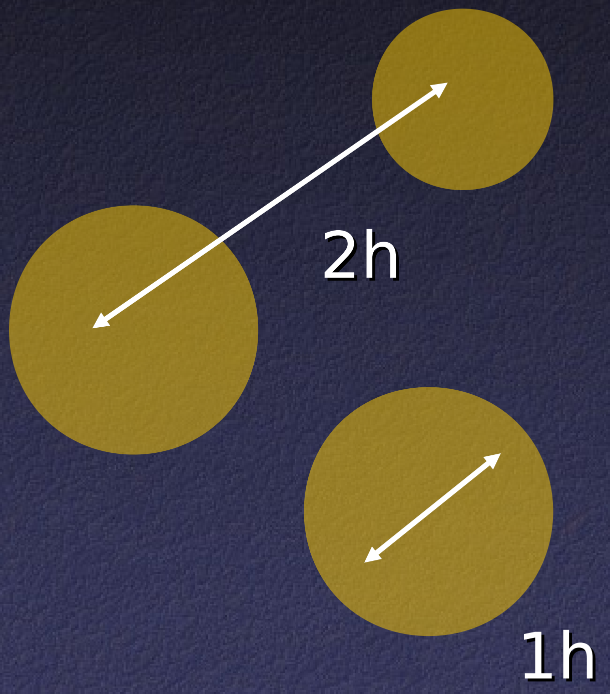
A simplified view of matter distribution in the Universe



Ideas

- All matter in the Universe lie inside dark matter halos.
- We can think the power spectrum as building by two terms. Correlations of matter which lie inside the same halo and correlations between different halos.
- We can apply the lineal theory to describe the large scale correlations.



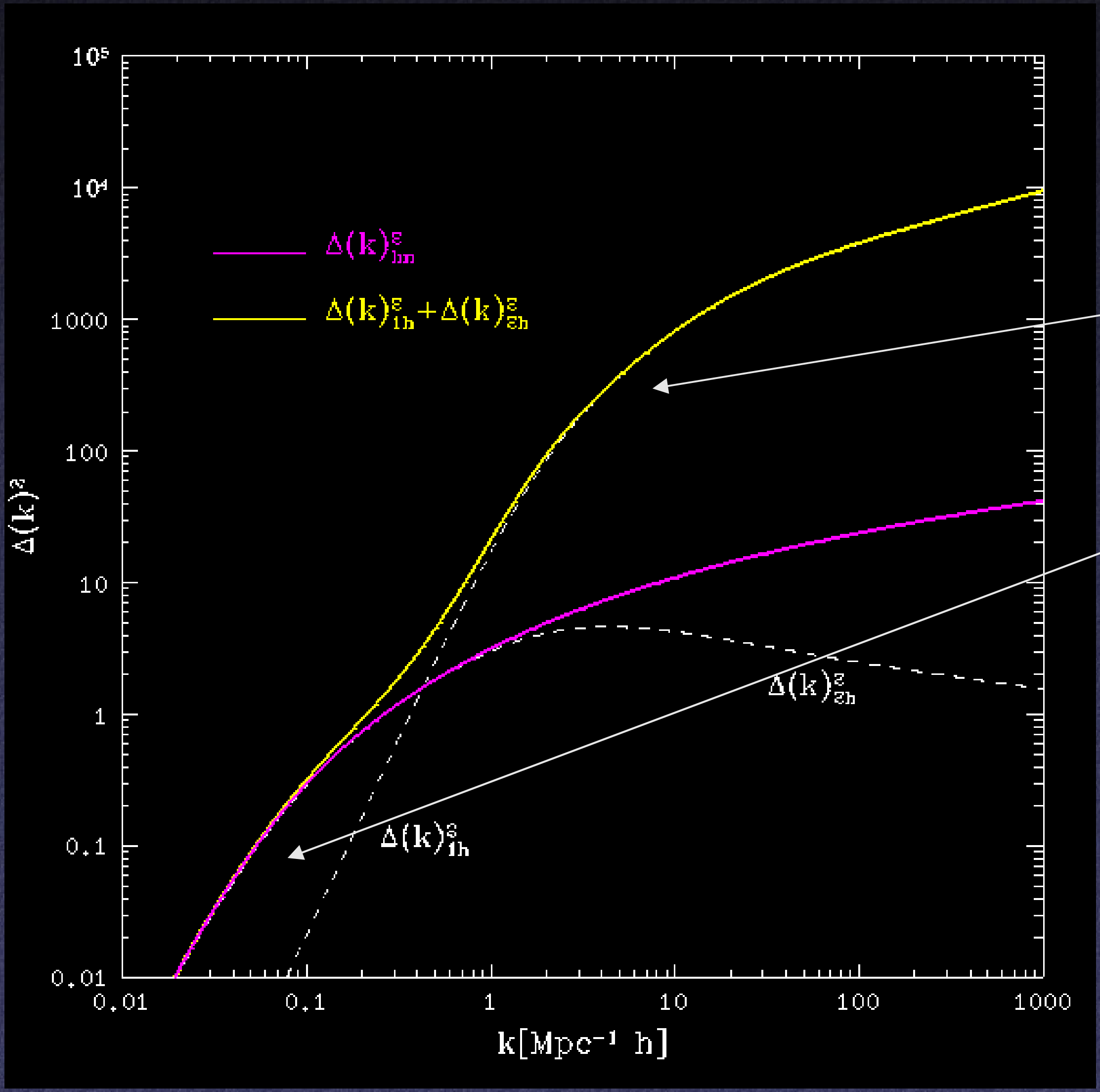
Ingredients

- **Dark matter halos mass function**
- **Density profile of dark matter halos**
- **Bias factor**
- **Halo Occupation Distribution**

  - Galaxy distribution (= dark matter)

  - Mean number of galaxies per halo (as function of halo's mass)

Power Spectrum

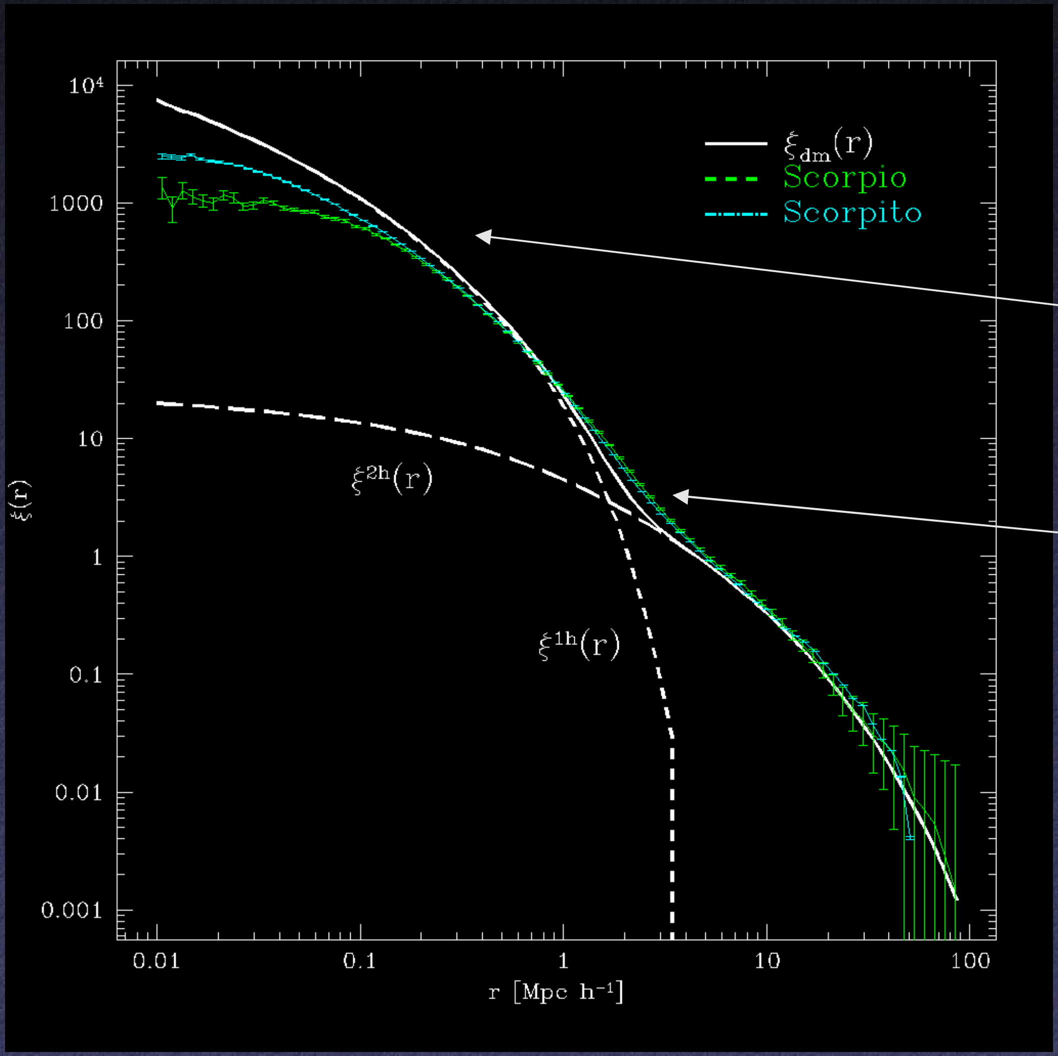


$$P_{dm}(k) = P_{dm}^{1h}(k) + P_{dm}^{2h}(k)$$

1-Halo Term 2-Halos Term

On small scales (< rvir) the 1-Halo term predominate, while on large scales the contribution is from the 2-Halo term.

Bi-puntual Correlation Function



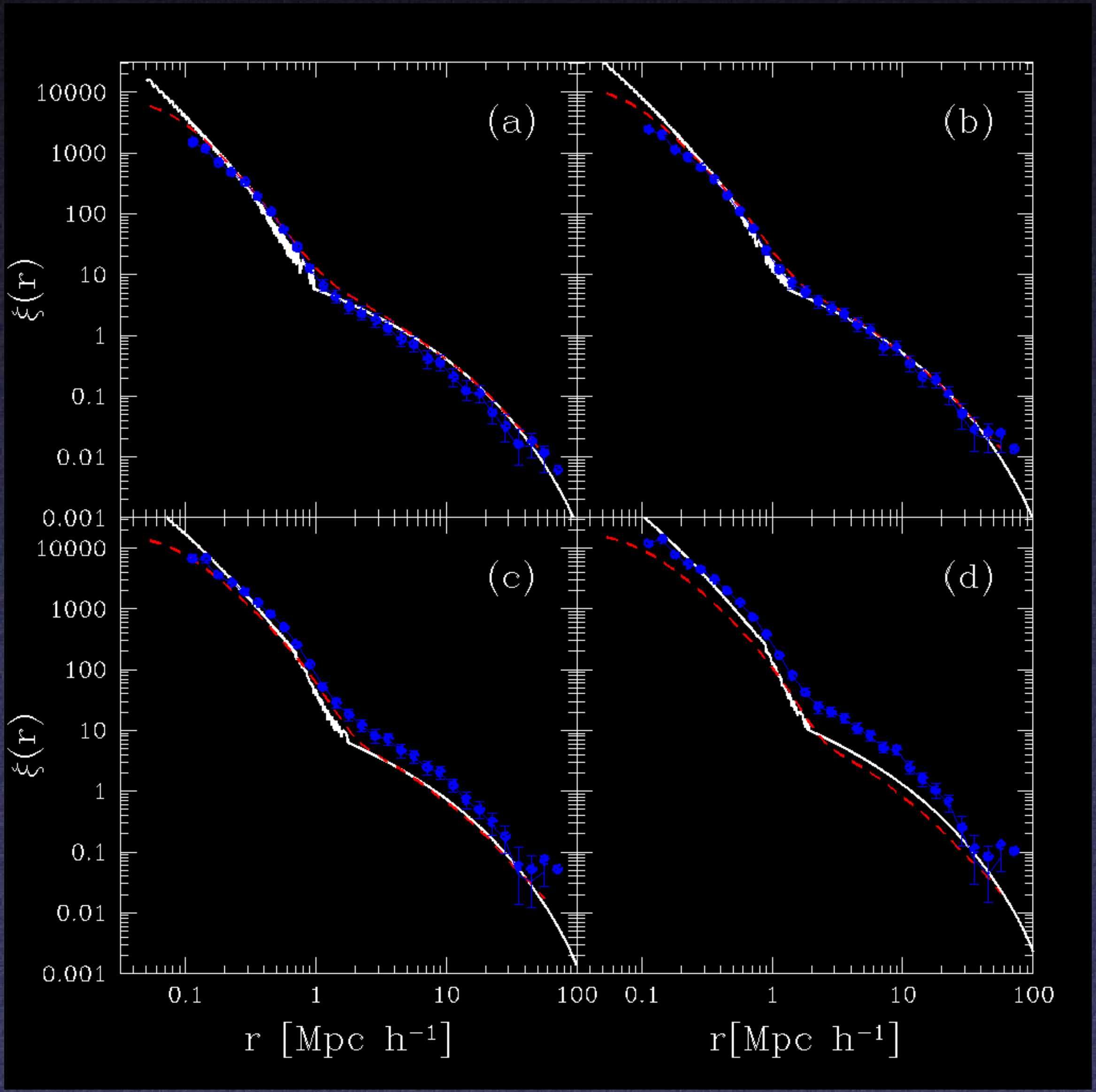
$$\xi_{dm}(r) = \xi_{dm}^{1h}(r) + \xi_{dm}^{2h}(r)$$

Low simulation resolution problem.

Aspherical halo density profile problem.

A comparation betweeen correlation function obtained from dark matter simulations and the theoretical prediction.

Cross Correlation Function Halo - Matter



a) $\log_{10} M > 12.5$

b) $\log_{10} M > 13.0$

c) $\log_{10} M > 13.5$

d) $\log_{10} M > 13.82$

The two term transition is more pronounced in cross correlation function than auto-correlation function.

Triaxial Halo Model

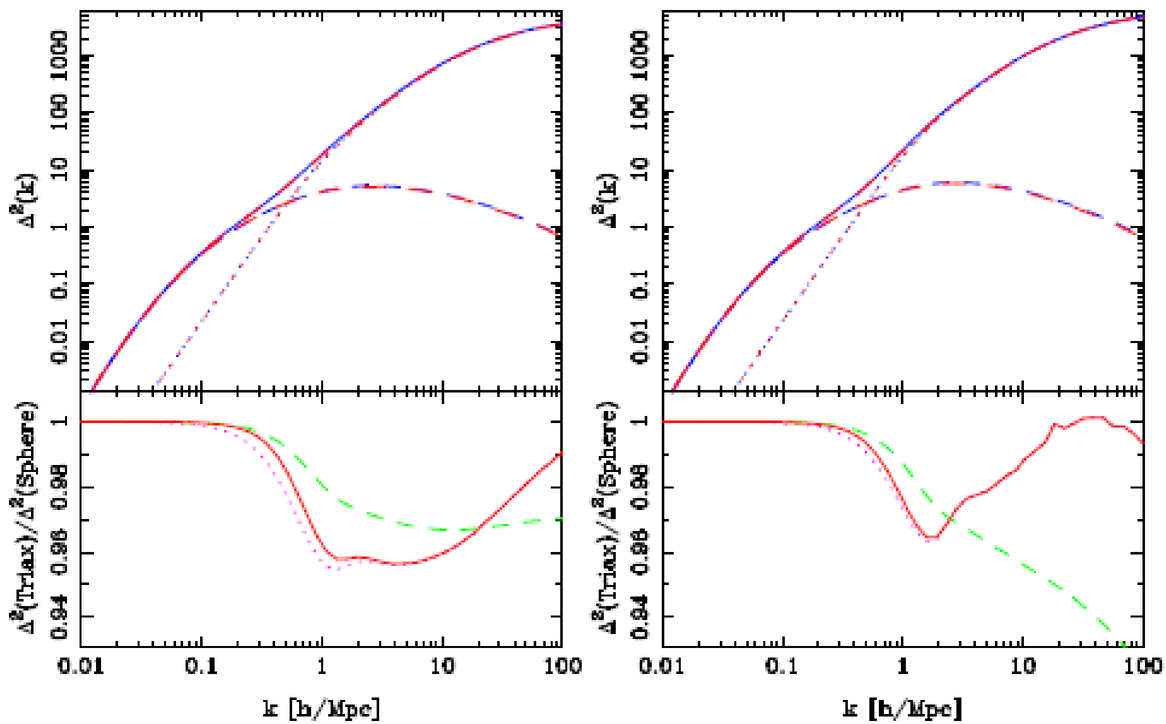


Figure 2. Dimensionless power spectrum in the triaxial halo model. Left panels show effects for the continuity profile model and right show the JS02 profile model. Top panels show: the total power spectrum (thick solid line); which is the sum of $P^{1\mathrm{H}}$ (dotted lines) and $P^{2\mathrm{H}}_{\mathrm{NA}}$ (dash lines); the total power from the spherical halo model (thin solid lines). Bottom panels show the ratios: total triaxial halo power to total spherical halo power (solid lines); triaxial 1-Halo to spherical 1-Halo (dotted lines); triaxial 2-Halo to spherical 2-Halo (dash lines).

Triaxial halos, intrinsic alignments and the dark matter power spectrum
Smith & Watts, 2004

Triaxial Halo Model

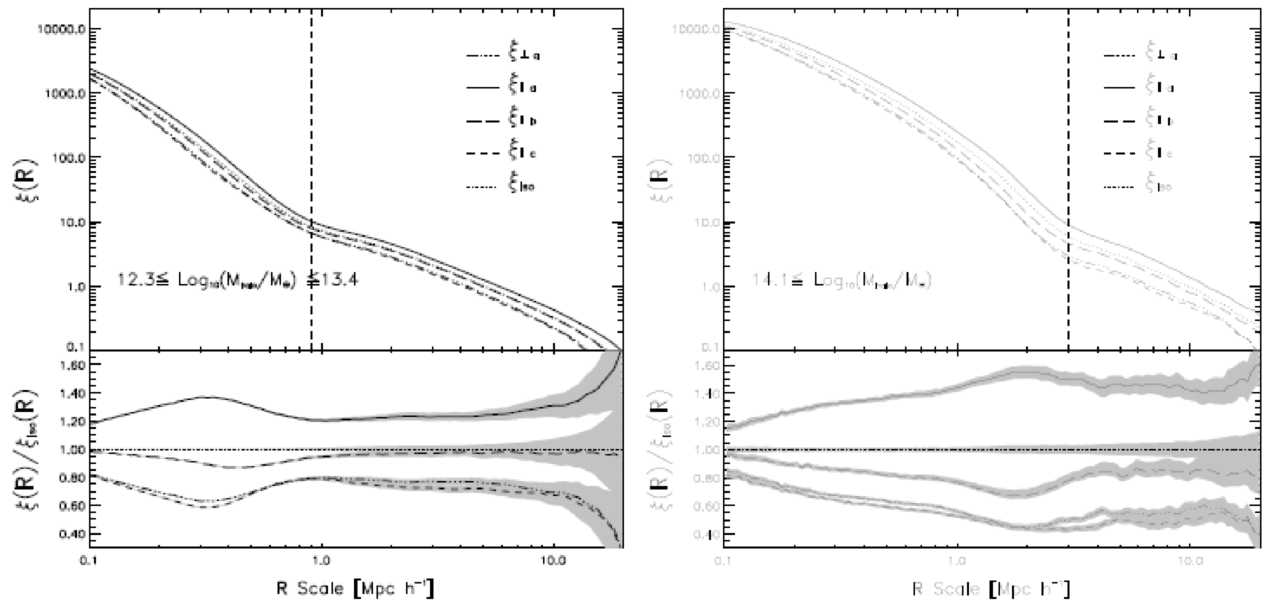


Figure 1. Left panel: Spatial Halo−Dark-matter correlation function of low mass halos in the numerical simulation. The solid, long dashed and short dashed lines show the correlation functions between halos and neighbour particles along the directions of the major, intermediate, and minor axes of the halo shape ellipsoid, respectively. The dotted line shows the results for the isotropic correlation obtained by using all the tracers regardless of the direction (i.e. the classical halo-particle cross-correlation function). The dotted-dashed lines correspond to the correlation function between halos and neighbour particles in the direction perpendicular to the halo shape major axis. The dashed vertical line represents the transition scale between the 1− and 2−halo terms of the cross-correlation function. Shaded areas indicate the 1−σ standard deviation around each measurement. The lower left subpanel shows ratios between the directional and isotropic correlation functions shown in the top-left panel. Right panel: same as left panel, for a high mass DM halo subsample obtained from the simulation.

Alignments of Galaxy Group Shapes with Large Scale Structure
Paz *et ál.*, 2011

Triaxial Halo Model: what are we working on?

$\vec{a} \equiv (a_1, a_2, a_3)$ eigenvalues of shape tensor.

$\vec{\epsilon} \equiv (\hat{e}_1, \hat{e}_2, \hat{e}_3)$ eigenvectors of shape tensor.

Selection function.

$$\xi_{hm}^{1h}(\vec{r}) = \frac{1}{\rho n_c} \int m dm \int\int\int d\vec{a} \int\int\int d\vec{\epsilon} U(\vec{r}, m, \vec{a}, \vec{\epsilon}) p(m, \vec{a}, \vec{\epsilon}) \psi(m, \vec{a}, \vec{\epsilon})$$

Dark matter density profile depending on mass, shape and orientation.

Probability distribution of finding an halo of mass m with eigenvalue *a* and eigenvector *e* of tensor shape.

Triaxial Halo Model: what are we working on?

mass function

$$p(\vec{x}, M, \vec{\epsilon}, \vec{a}) = \frac{1}{V}\frac{n(M)}{\overline{n}}p(\epsilon)p(a|M)$$

It rests define *p(a|M). We* can obtain it from drak matter simulation.

uniform probability for the halo orientation

$$\begin{aligned} p(\vec{\epsilon})d\vec{\epsilon} &\equiv p(\alpha,\beta\gamma)d\alpha d\beta d\gamma \\ &= \frac{1}{2\pi}\frac{1}{2}\frac{1}{2\pi}d\alpha d(cos\beta)d\gamma \end{aligned}$$

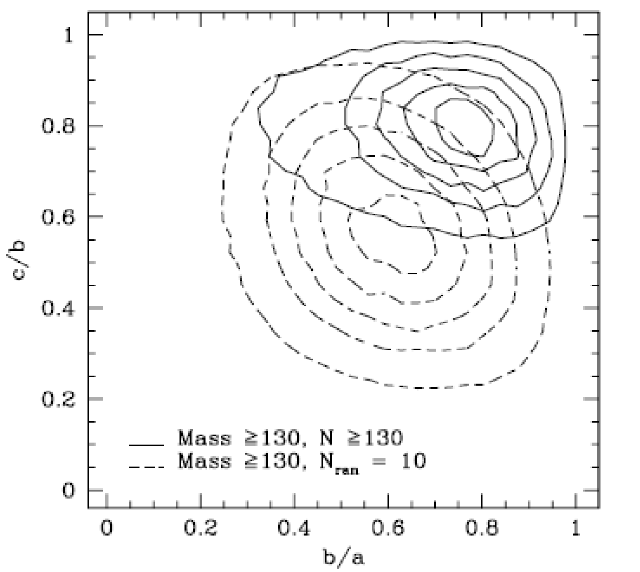


Figure 1. Contour maps of the scatter-plot of b/a vs. c/b semi-axis ratios (see text) for groups with masses $M > 10^{12} M_{\odot}$. Solid lines correspond to the values estimated using all members, while dashed lines show b/a vs. c/b when only 10 random group members are used in the calculation. Contours enclose 10, 30, 50, 70, and 90% of the b/a vs. c/b points (inner to outer contours, respectively).

Paz *et ál.*, 2005

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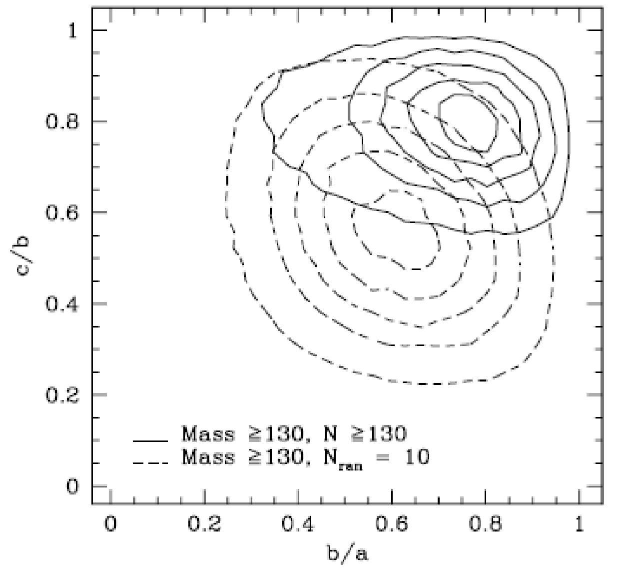
Ellipsoidal density profile. Jing & Suto, 2002

$$\frac{R^2}{c^2} = \frac{x^2}{a^2} + \frac{y^2}{b^2} + \frac{z^2}{c^2}$$

$$\frac{\rho(R)}{\rho_{\rm crit}} = \frac{\delta_c}{(R/R_0)^\alpha (1 + R/R_0)^{3-\alpha}},$$



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$$\xi^{2h}_{hm}(\vec{r}) = -1 \quad + \quad \frac{1}{\rho n_c}\int dm_1 \int\int\int d\vec{a}_1 \int\int\int d\vec{\epsilon}_1 \psi(m_1, \vec{a}_1, \vec{\epsilon}_1) \times$$
$$\int m_2 dm_2 \int\int\int d\vec{a}_2 \int\int\int d\vec{\epsilon}_2 \int\int\int d\vec{y} U(\vec{r}-\vec{y}, m_2, \vec{a}_2, \vec{\epsilon}_2) p(1) p(2) \xi(\vec{y}, 1, 2)$$

Correlation of dark matter halos with mass m1 and m2 (lineal theory times bias factor).

Triaxial Halo Model: what are we working on?

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Don't panic!. You can reduce it to 12 integrals if you fix central halo orientation, or less, if you work in fourier space.

Correlation of dark matter halos with mass m1 and m2 (lineal theory times bias factor).

Triaxial Halo Model: what are we working on?

$$\xi_{hm}^{2h}(\vec{r}) = -1 \quad + \quad \frac{1}{\overline{\rho n_c}} \int dm_1 \int\int\int d\vec{a}_1 \int\int\int d\vec{\epsilon}_1 \psi(m_1, \vec{a}_1, \vec{\epsilon}_1) \times$$
$$\int m_2 dm_2 \int\int\int d\vec{a}_2 \int\int\int d\vec{\epsilon}_2 \int\int\int d\vec{y} U(\vec{r} - \vec{y}, m_2, \vec{a}_2, \vec{\epsilon}_2) p(1) p(2) \xi(\vec{y}, 1, 2)$$

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That's all folks, thanks you....