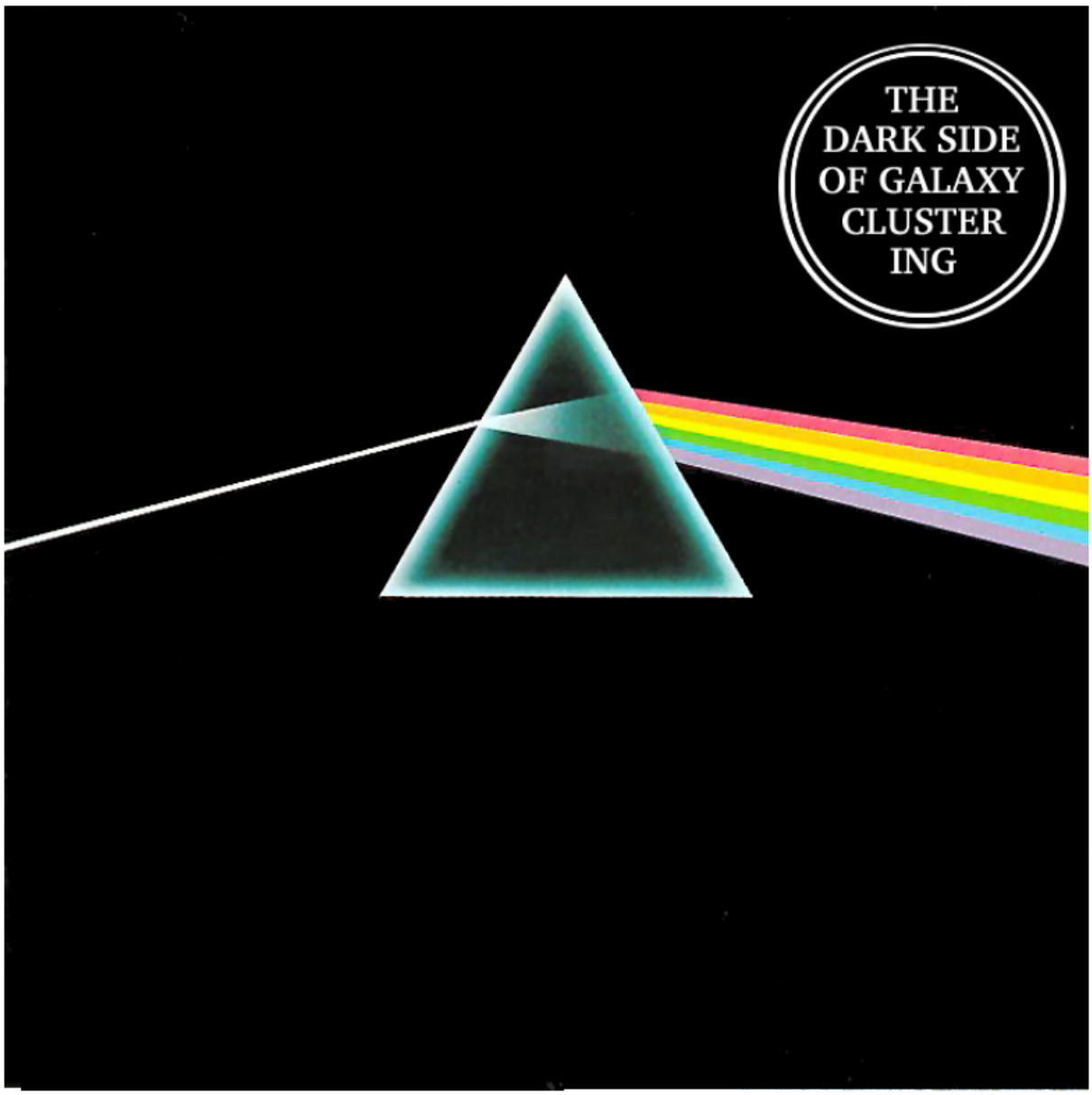

THE
DARK SIDE
OF GALAXY
CLUSTER
ING

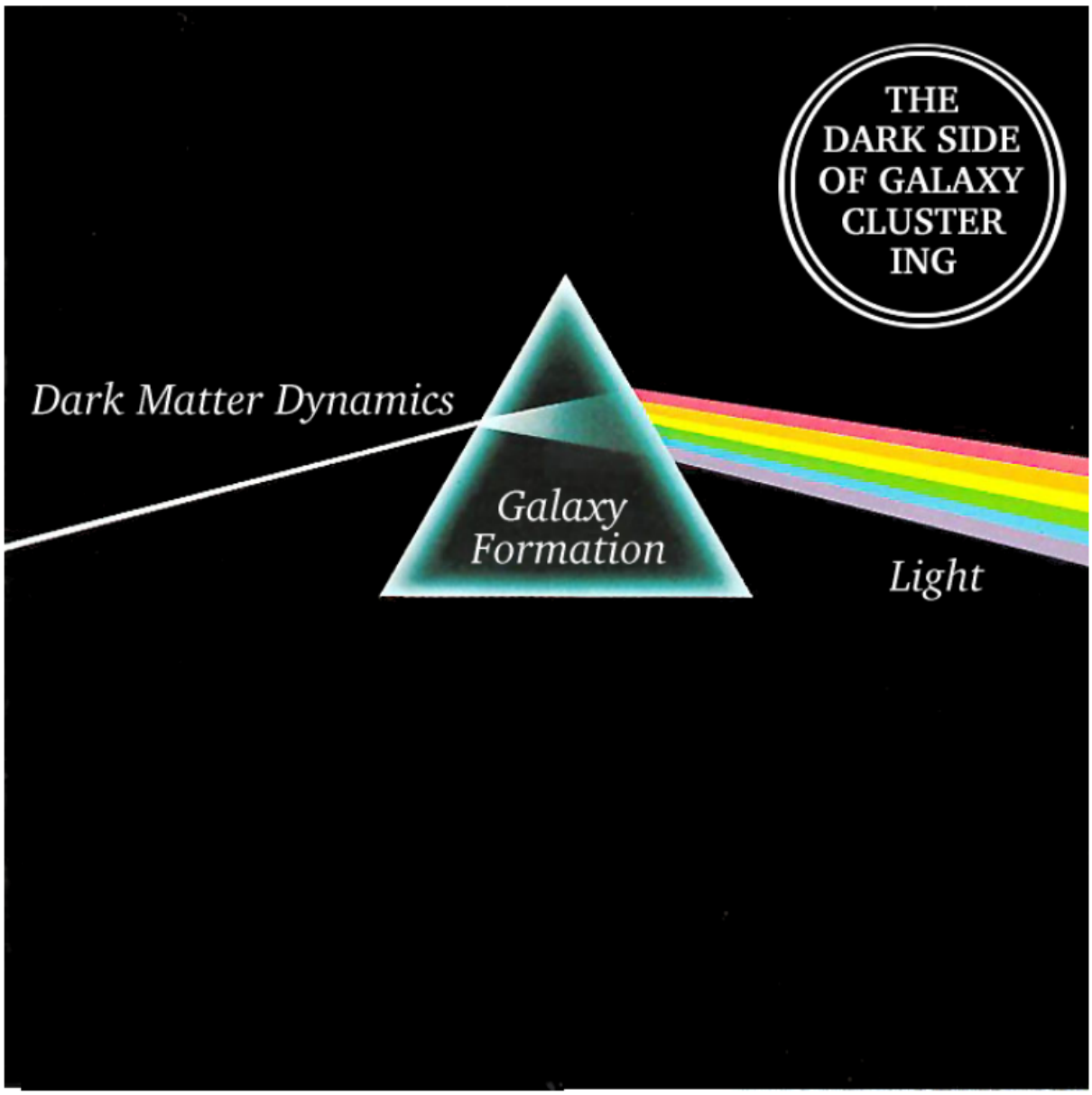
Risa Wechsler
(U. Chicago)

Anatoly
Klypin
(NMSU)

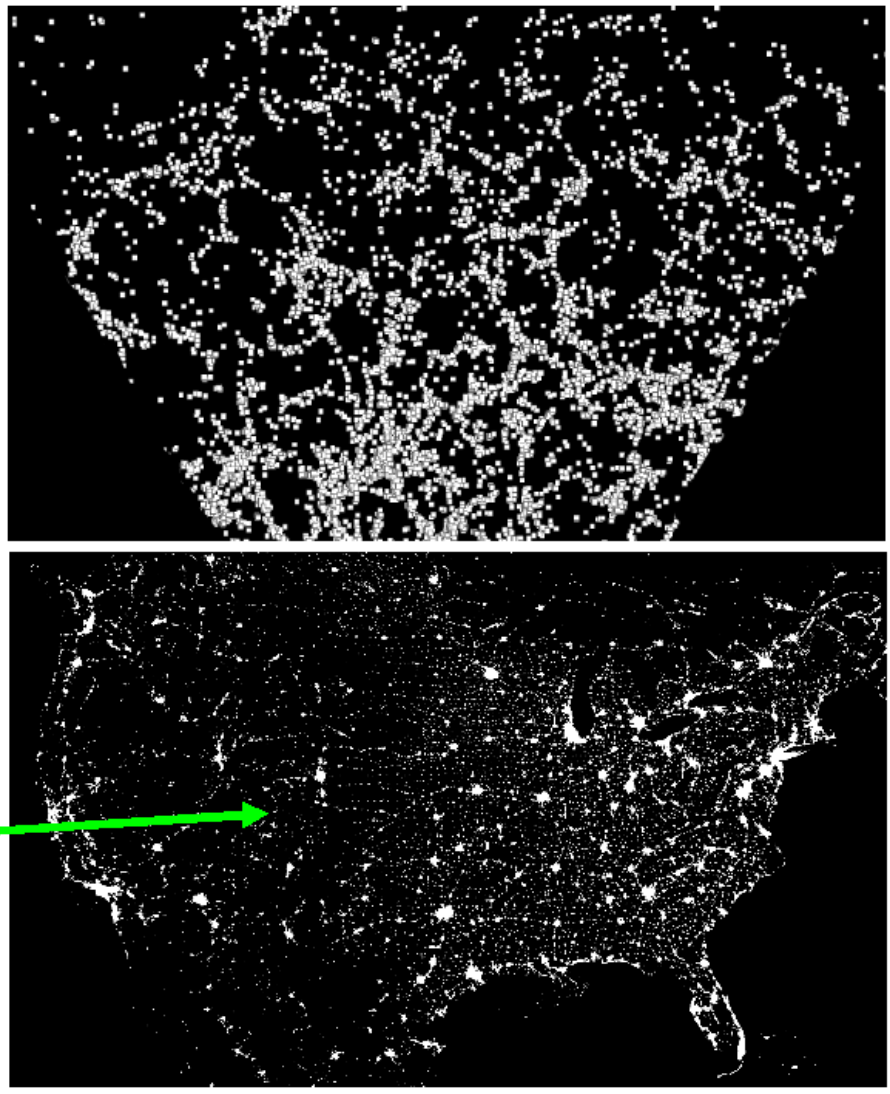
Andreas
Berlind
(NYU)

Andrey Kravtsov
(University of Chicago)

et al.


THE
DARK SIDE
OF GALAXY
CLUSTER
ING
Dark Matter Dynamics
Galaxy
Formation
Light

are we fooled by the bright lights?

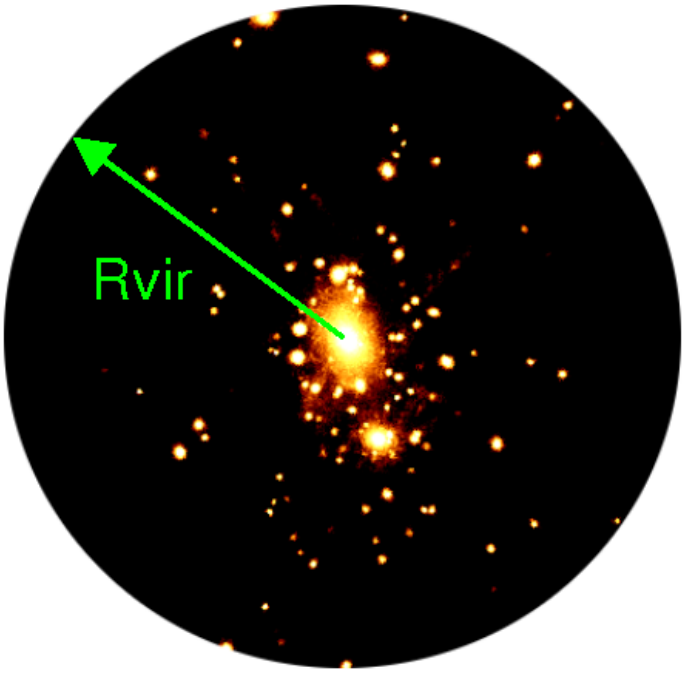


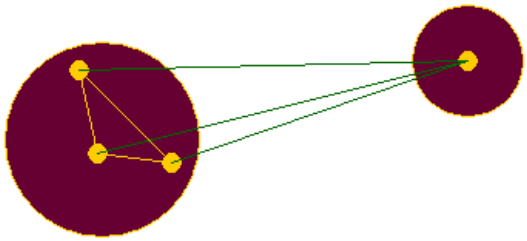
A portion of the SDSS LRG sample

You are here

Halo Occupation Distribution (HOD)

P(N/M) probability for a halo of mass *M* to harbor *N* galaxies





$$\langle N \rangle_M = \int dN P(N|M) N_M,$$

$$\langle N(N-1) \rangle_M = \int dN P(N|M) N_M (N_M - 1).$$

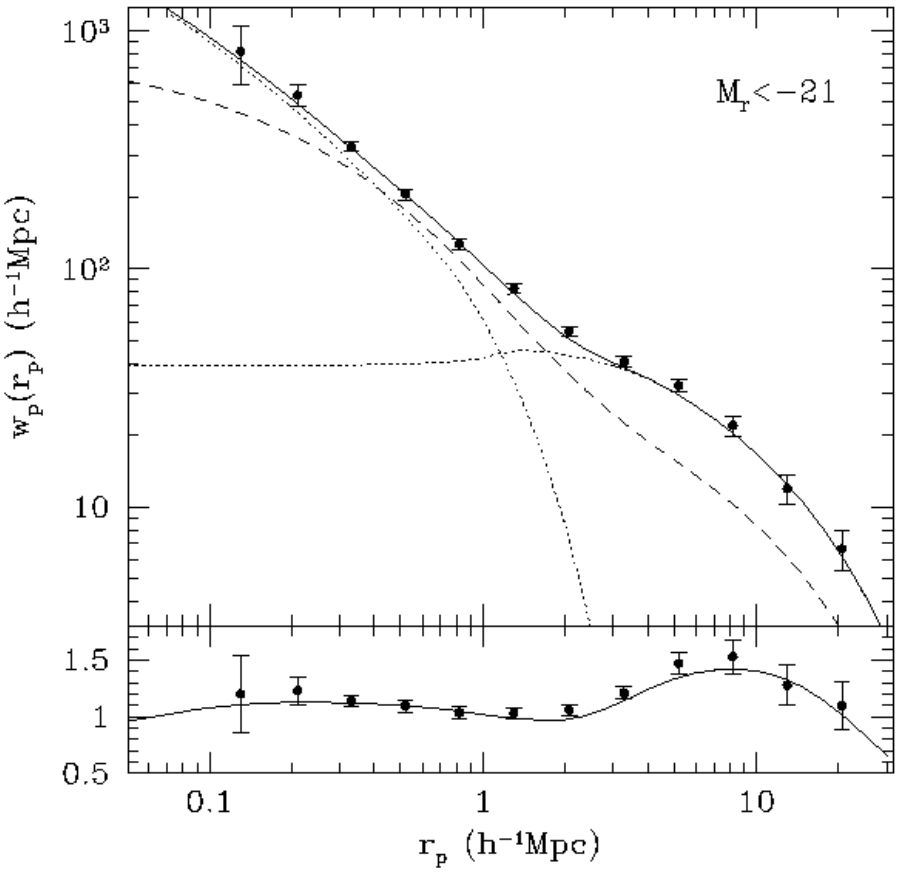
$$\xi_{\rm gg}(r) = \xi^{\rm 1h}_{\rm gg}(r) + \xi^{\rm 2h}_{\rm gg}(r).$$

$$\xi^{\rm 1h}_{\rm gg}(r) = \frac{1}{2}\,\bar{n}_{\rm g}^{-2} \int n(M) \langle N(N-1) \rangle_M \lambda(r|M)\, dM;$$

$$\xi^{\rm 2h}_{\rm gg}(r) = \xi^{\rm lin}_{\rm mm}(r)\; \bar{n}_{\rm g}^{-2} \int n(M_1) b_h(M_1) \langle N \rangle_{M_1}\, dM_1 \times \int n(M_2) b_h(M_2) \langle N \rangle_{M_2} \lambda(r|M_1, M_2)\, dM_2$$

Departures from the power law correlation function

as predicted by the Halo Model



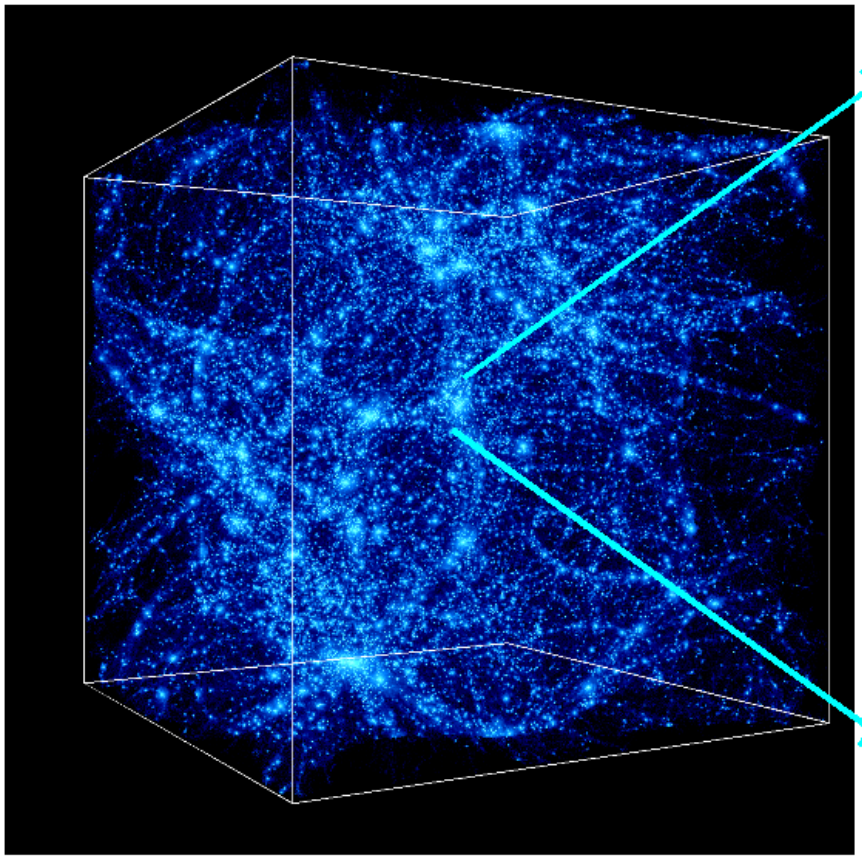
Zehavi et al. 2003

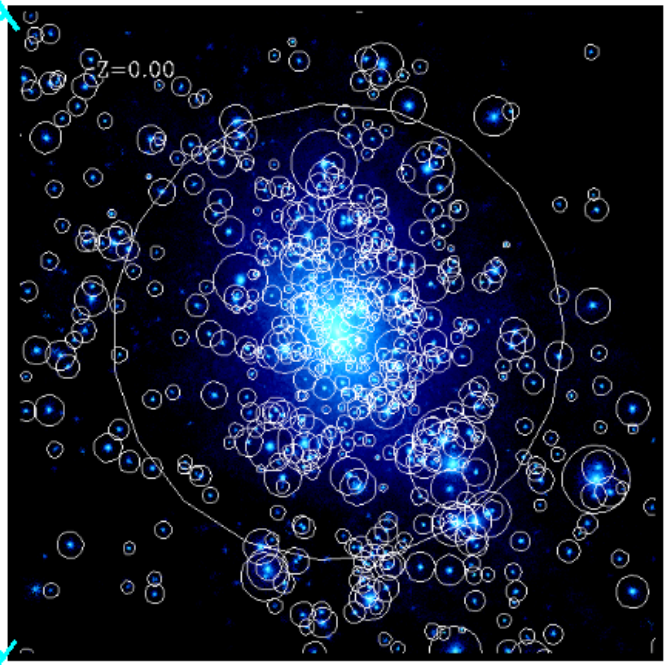
HOD in dissipationless simulations

LCDM 80h^{-1} Mpc; σ_8=0.75,0.9,1.0;

m_p=3.1x10$^8 h^{-1}$ Msun;

$\varepsilon = 0.5h^{-1}$ kpc



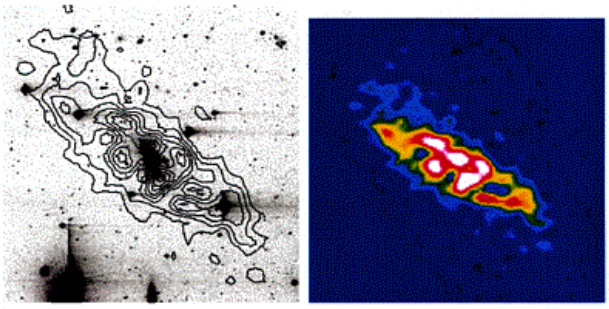


the Bound Density Maxima (BDM)
halo finding algorithm
(Klypin et al. 1999)

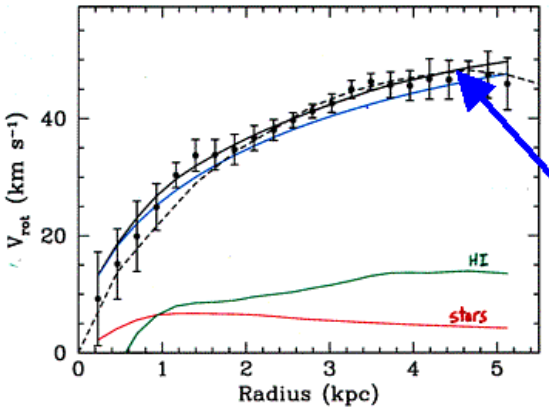
Vmax - the poor man's (theorist's) luminosity

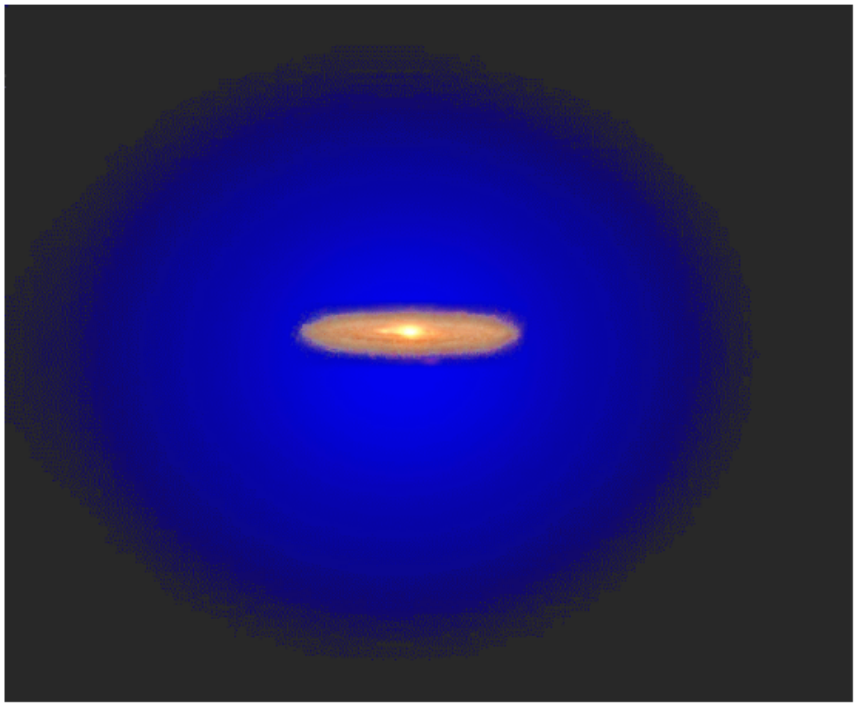
to construct samples select all halos with Vmax > threshold

DDO 154



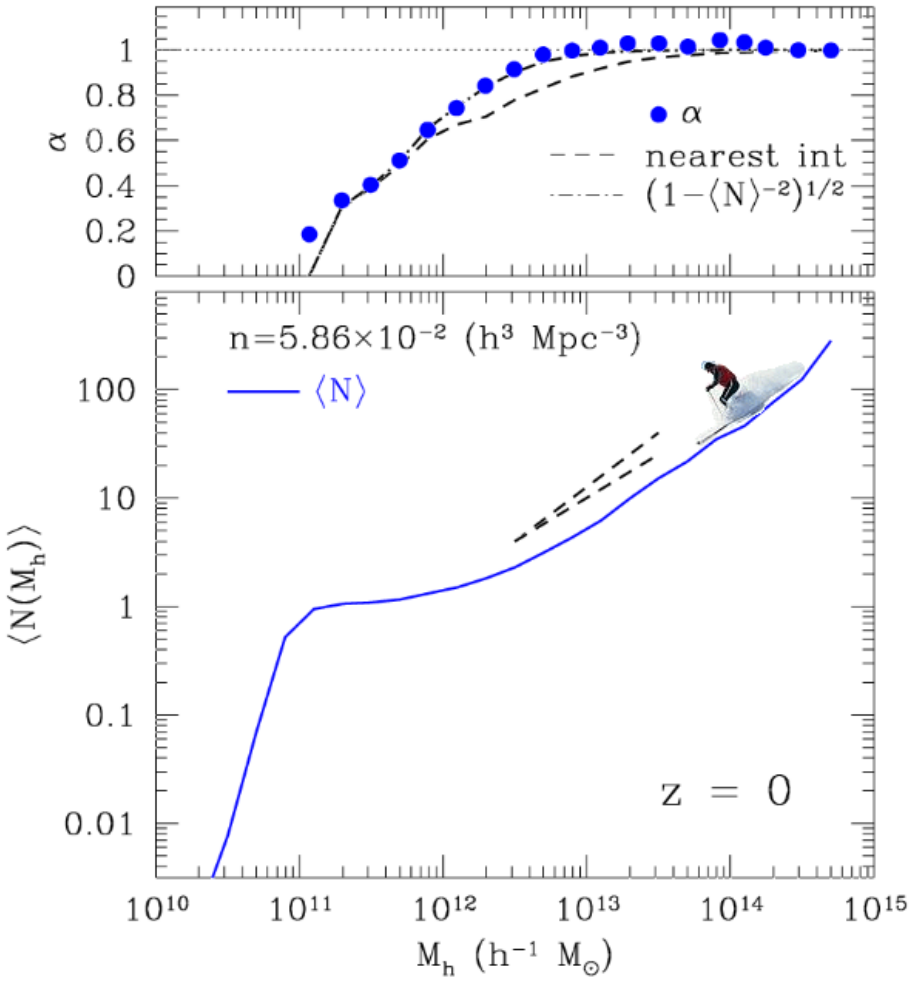
(Original HI data from Carignan & Purton, 1999)





Vmax = the maximum of circular velocity curve

HOD of galactic halos



$$\alpha^2 \equiv \frac{\langle N(N-1)\rangle}{\langle N\rangle^2}$$

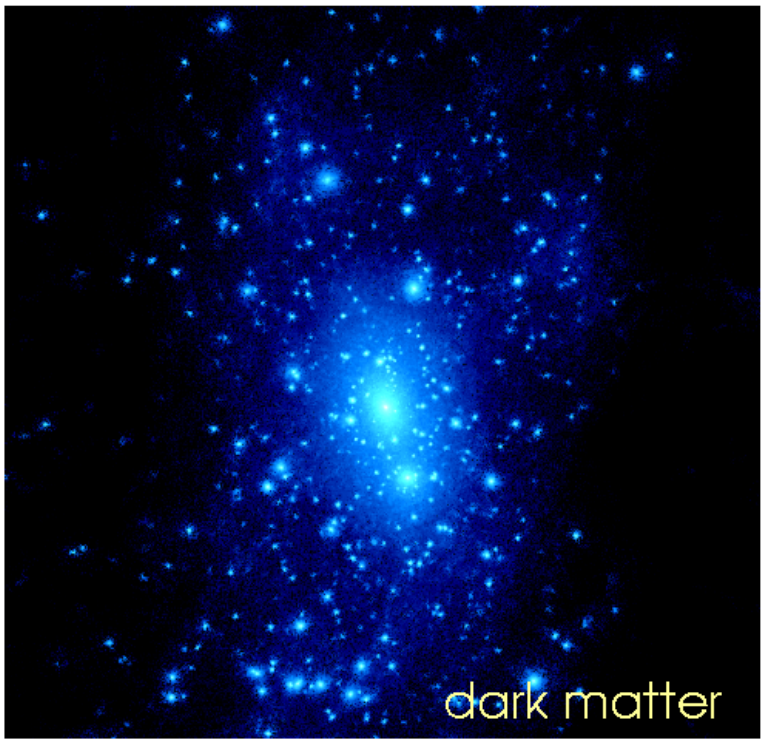
Average number of galactic halos

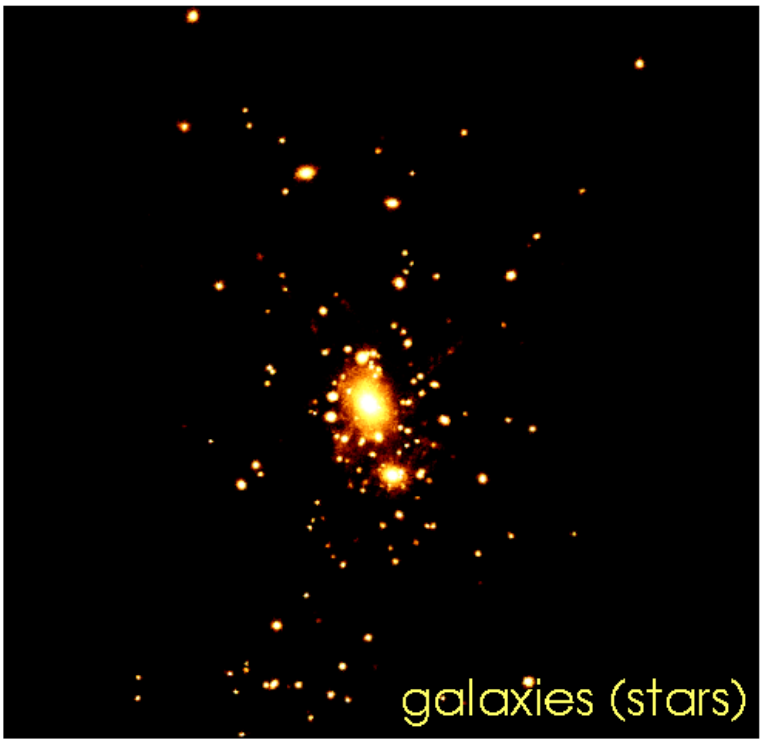
Host halo mass

Galaxies in a halo:
central galaxy + a population of satellite galaxies

$$N(M) = N_s + 1$$

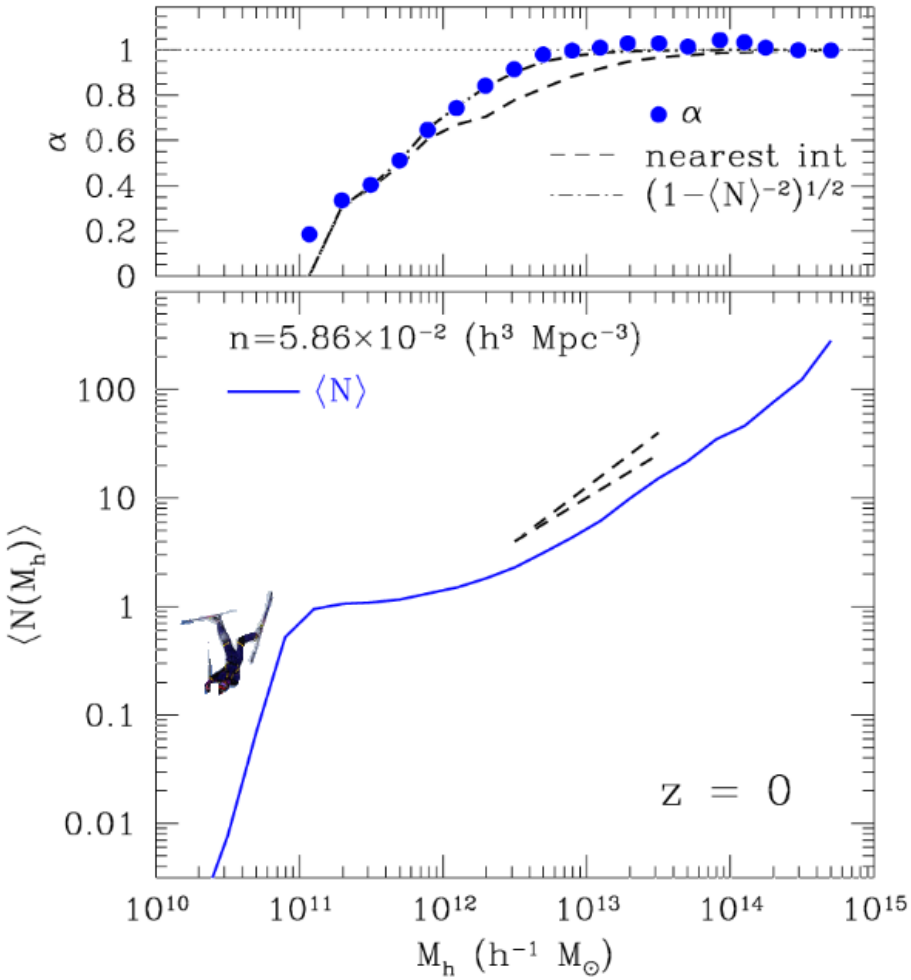
Virgo size cluster in a cosmological simulation
with gasdynamics and starformation (Nagai & Kravtsov 2004)





HOD of galactic halos

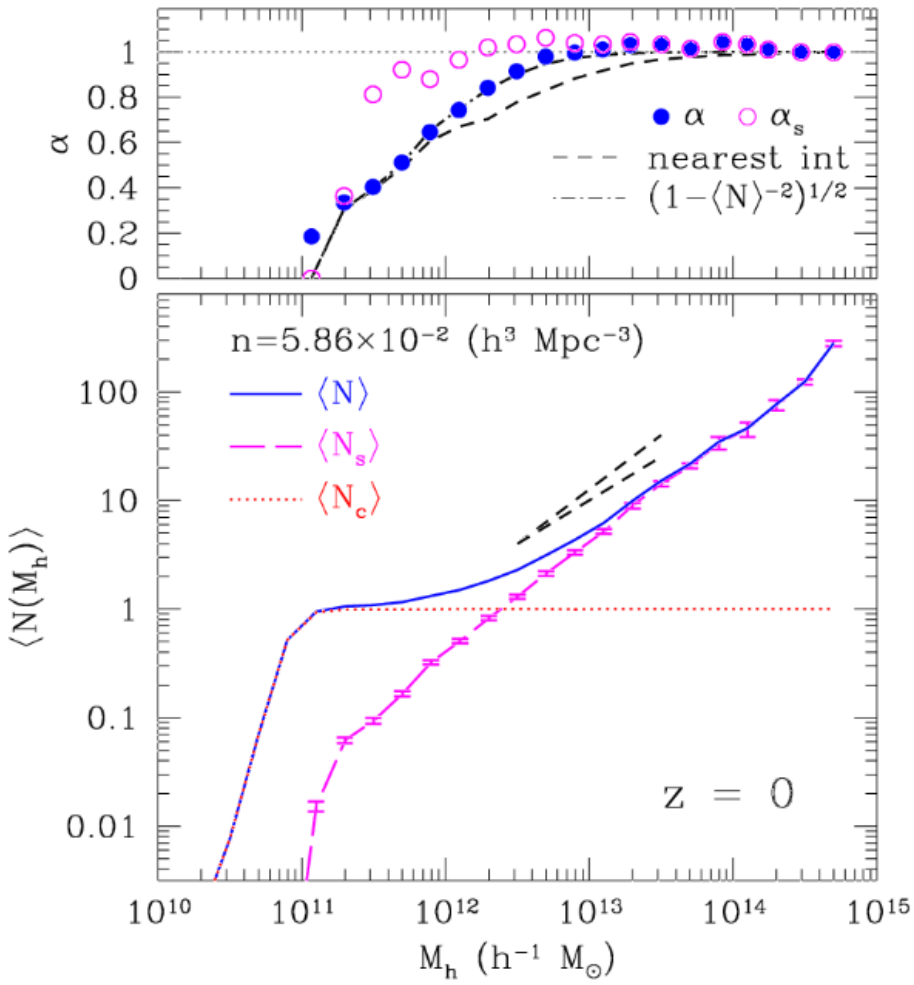
$$\alpha^2 \equiv \frac{\langle N(N-1)\rangle}{\langle N\rangle^2}$$



Average number of galactic halos

Host halo mass

Anatomy of the HOD



Average number of galactic halos

Host halo mass

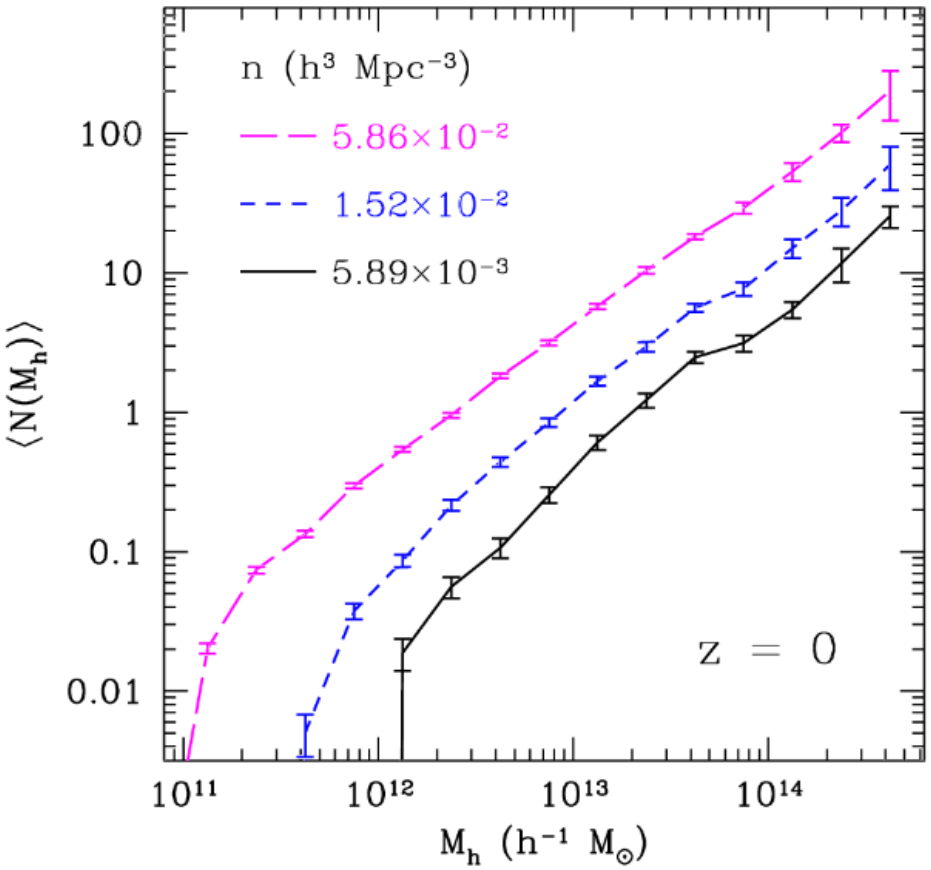
$$\alpha^2 \equiv \frac{\langle N(N-1)\rangle}{\langle N\rangle^2}$$

$$= 1 - \frac{1}{\langle N\rangle^2}$$

if satellite HOD is Poisson

Satellite HOD: scaling with overdensity

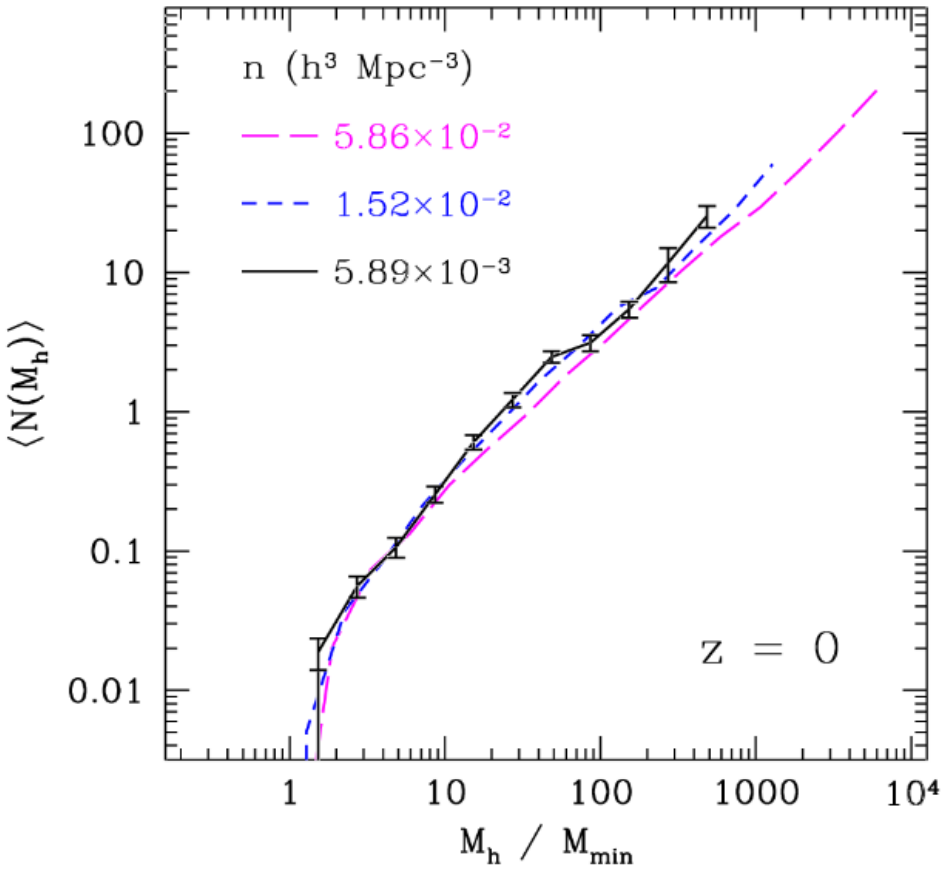
Average number of galactic halos



Host halo mass

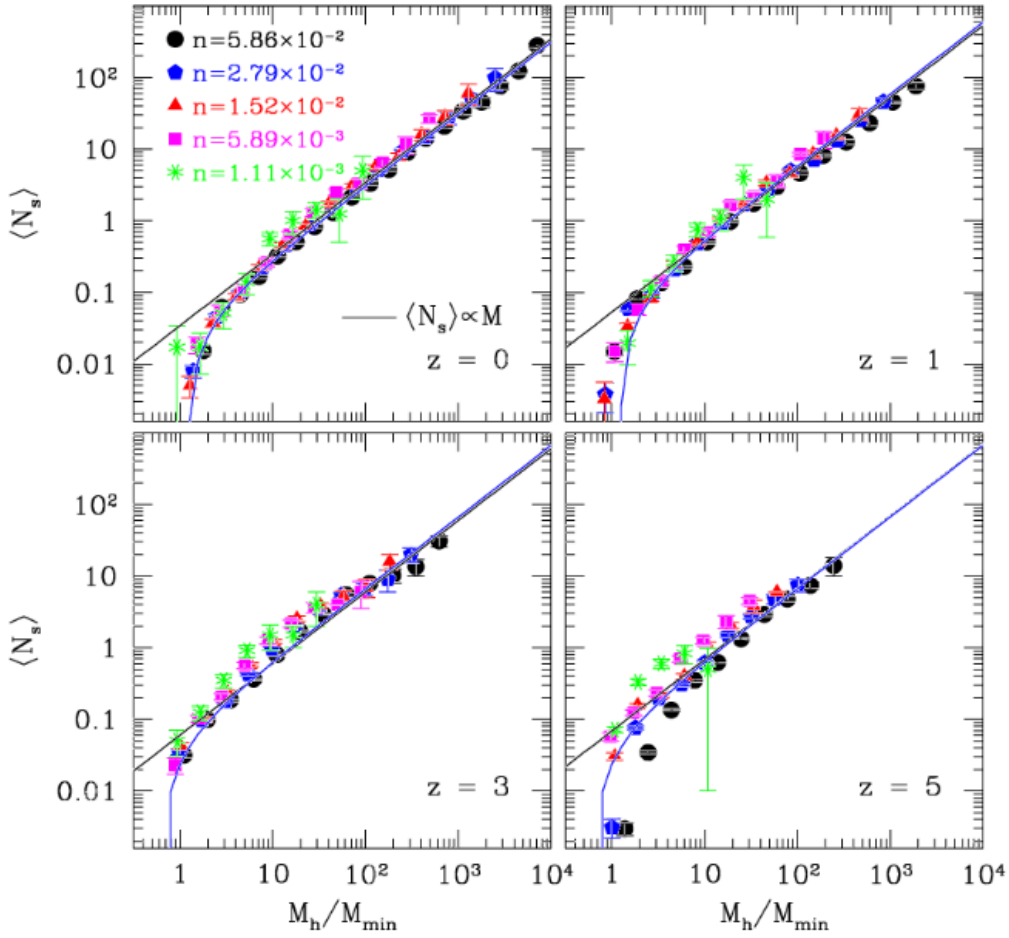
Satellite HOD: scaling with overdensity

Average number of galactic halos



Host halo mass

Average number of *satellites* as a function of halo mass (the first moment of the HOD)



$$\langle N_s \rangle = (M/M_1)^\beta$$

or more accurately:

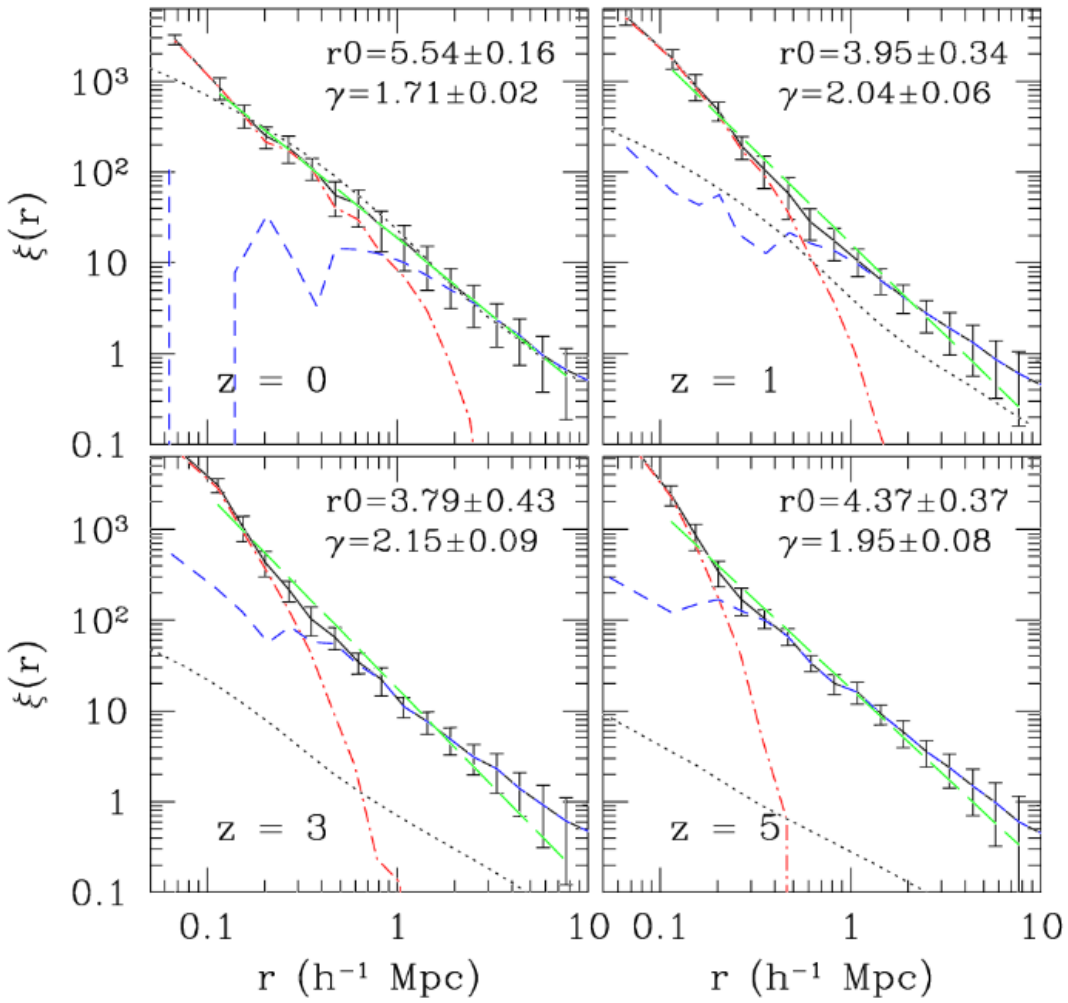
$$\langle N_s \rangle = (M/M_1 - C)^\beta$$

$$M_1 \approx 20 - 30 M_{\rm min}$$

$$C \approx 0.01 - 0.04$$

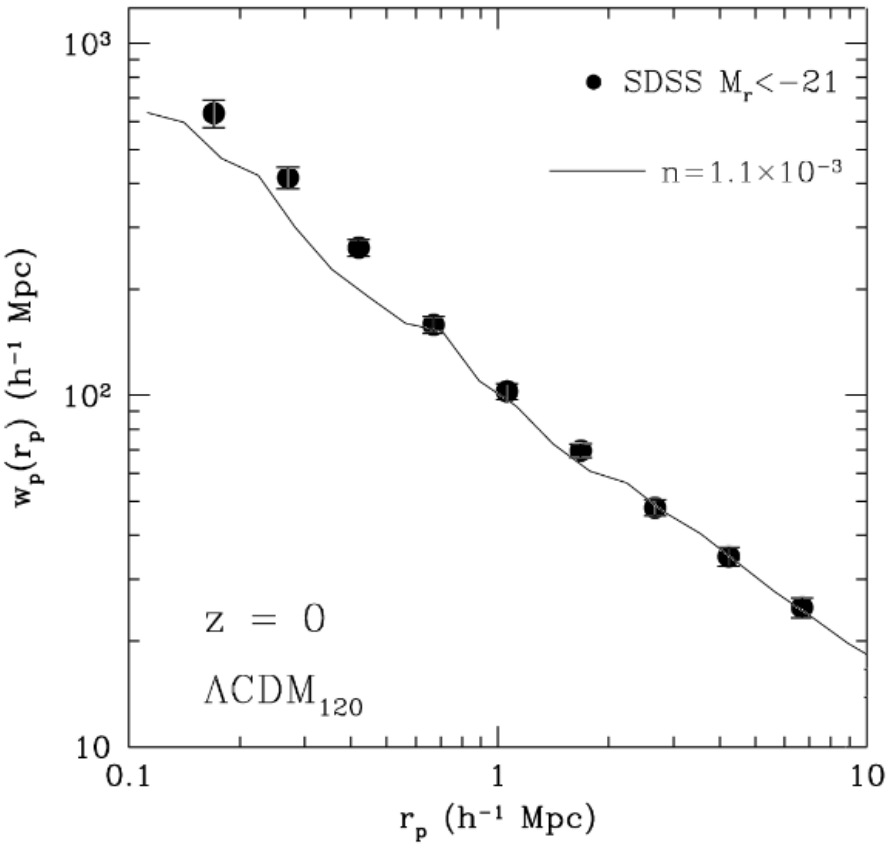
The scatter about the mean is Poisson

2- point correlation function of galactic halos

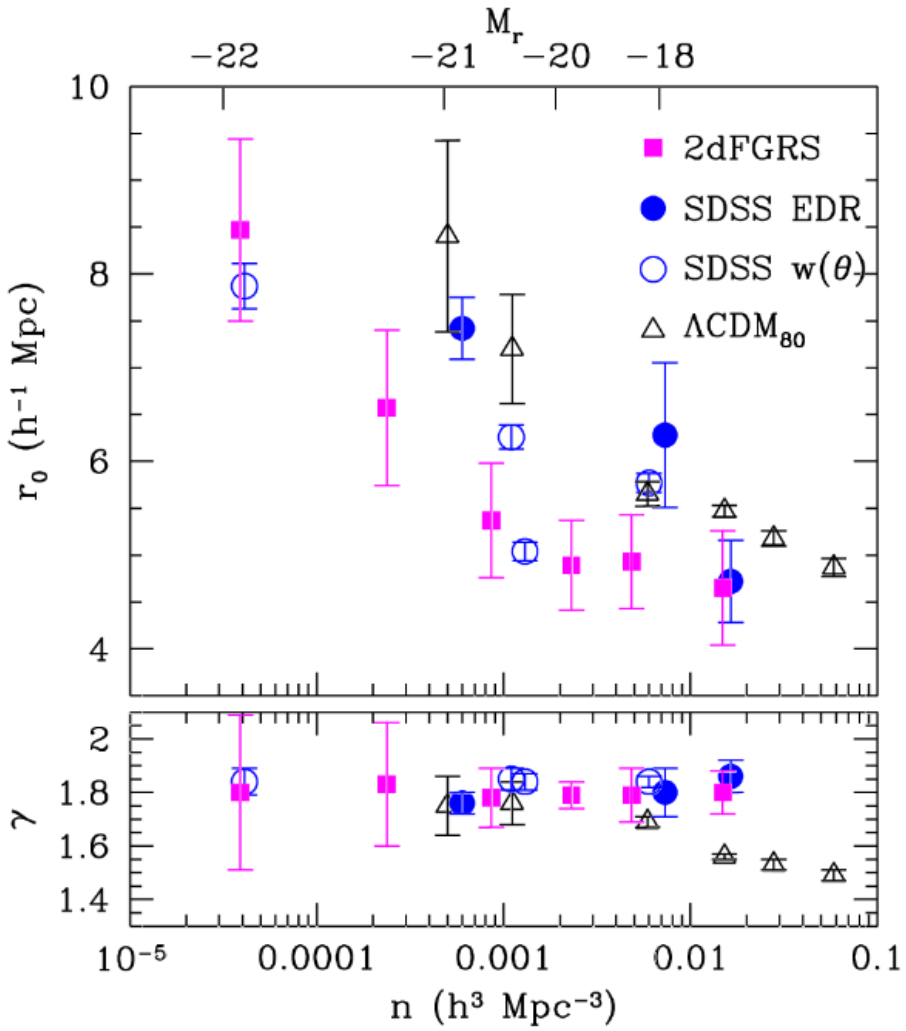


2- point correlation function of galactic halos simulation vs SDSS

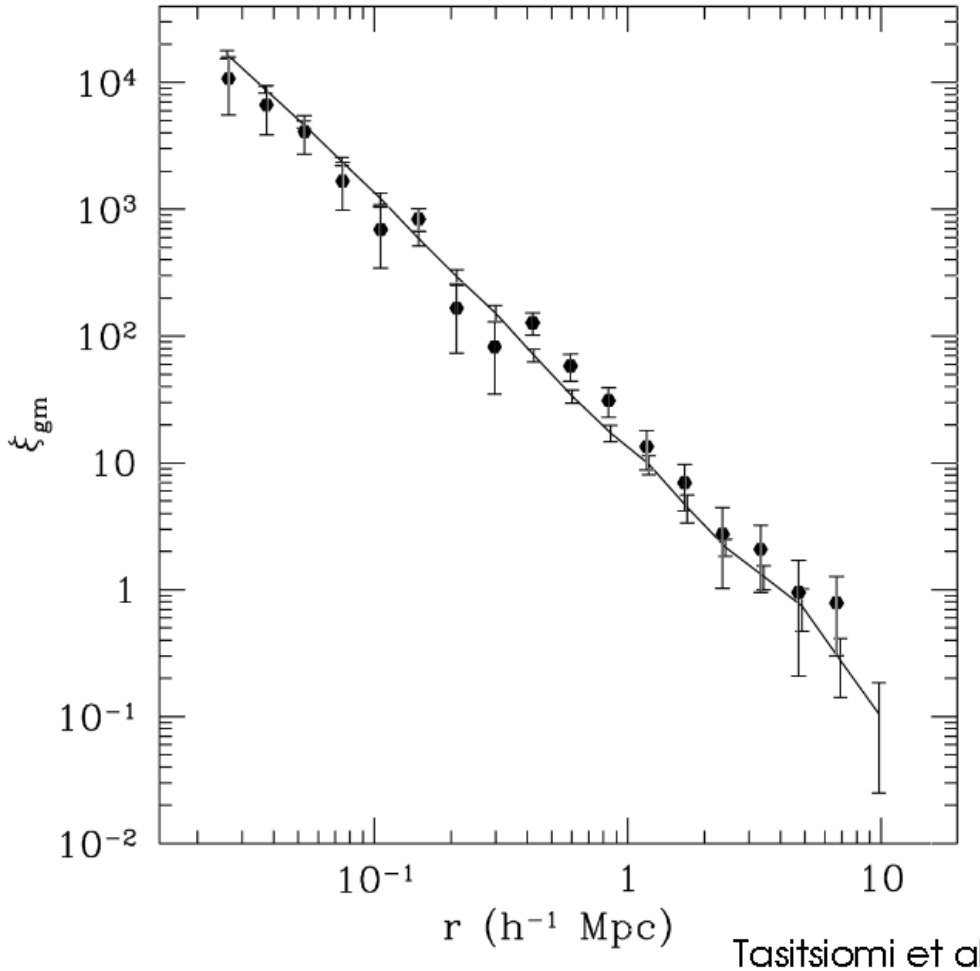
$n_h(>\mathrm{Vmax}) = n_g(>\mathrm{Lr})$



Correlation length and CF slope



galaxy- mass correlation function comparison with SDSS



data:
Sheldon et al. 2003,
(astro- ph/0312036)

Tasitsiomi et al. 2004, in preparation

Conclusions

- The Halo Occupation Distribution can be understood as a sum of probabilities for a halo to host a central galaxy and a certain number of satellites.

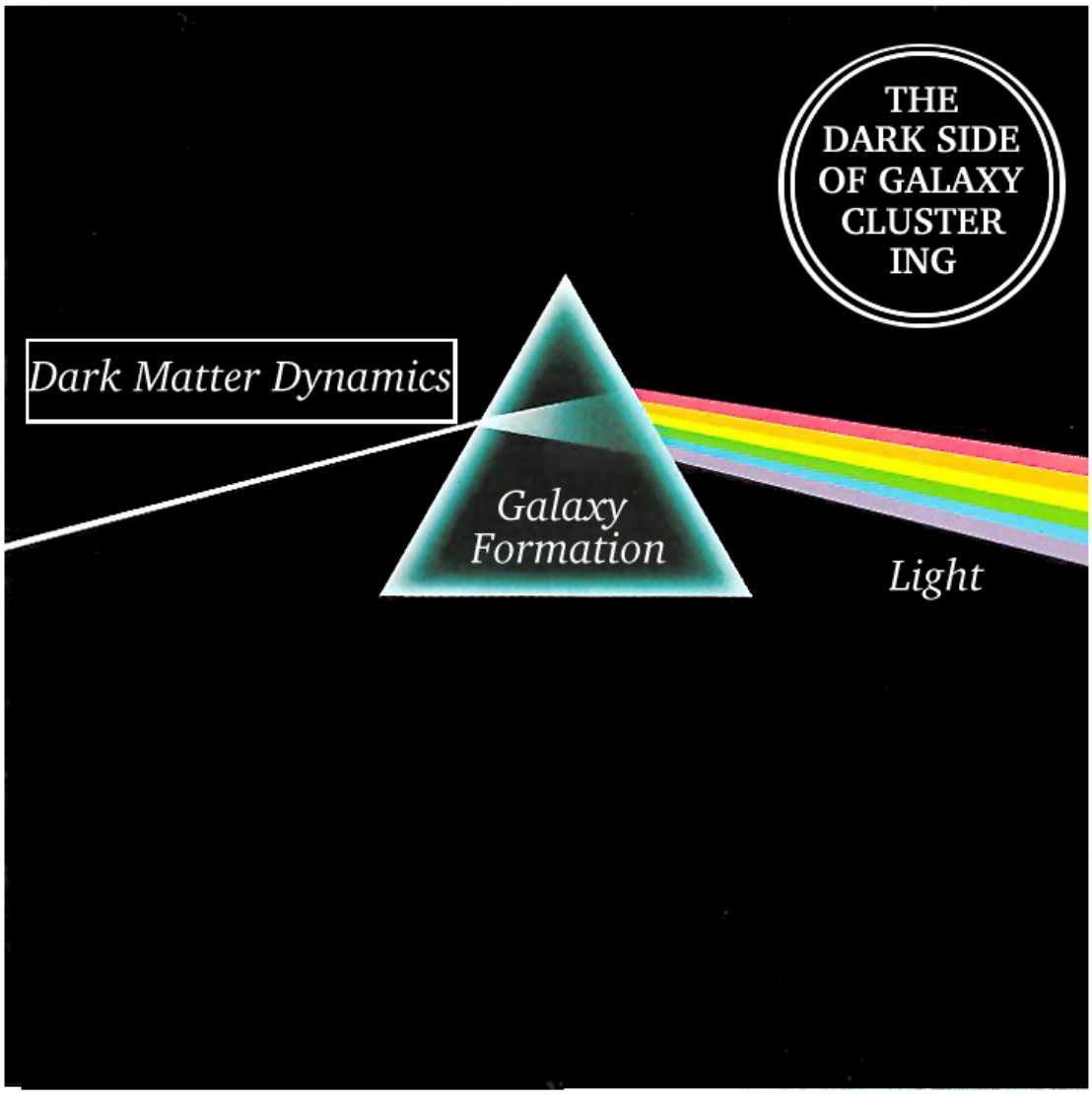
The former is a step function, while the latter is Poisson pdf with the mean: $\langle N_s \rangle = (M/M_1 - C)^\beta$

This provides a simple accurate HOD model for data interpretation and Halo Model analyses

- Clustering of dark matter halos matches the clustering of the overall galaxy population rather well.

Dark matter dynamics thus appears to be the primary driver of galaxy clustering.

Kravtsov, Berlind, Wechsler, Klypin et al. 2003, ApJ submitted (astro- ph/0308519)


THE
DARK SIDE
OF GALAXY
CLUSTER
ING
Dark Matter Dynamics
Galaxy
Formation
Light