Origin of galaxy alignment on large and small scales

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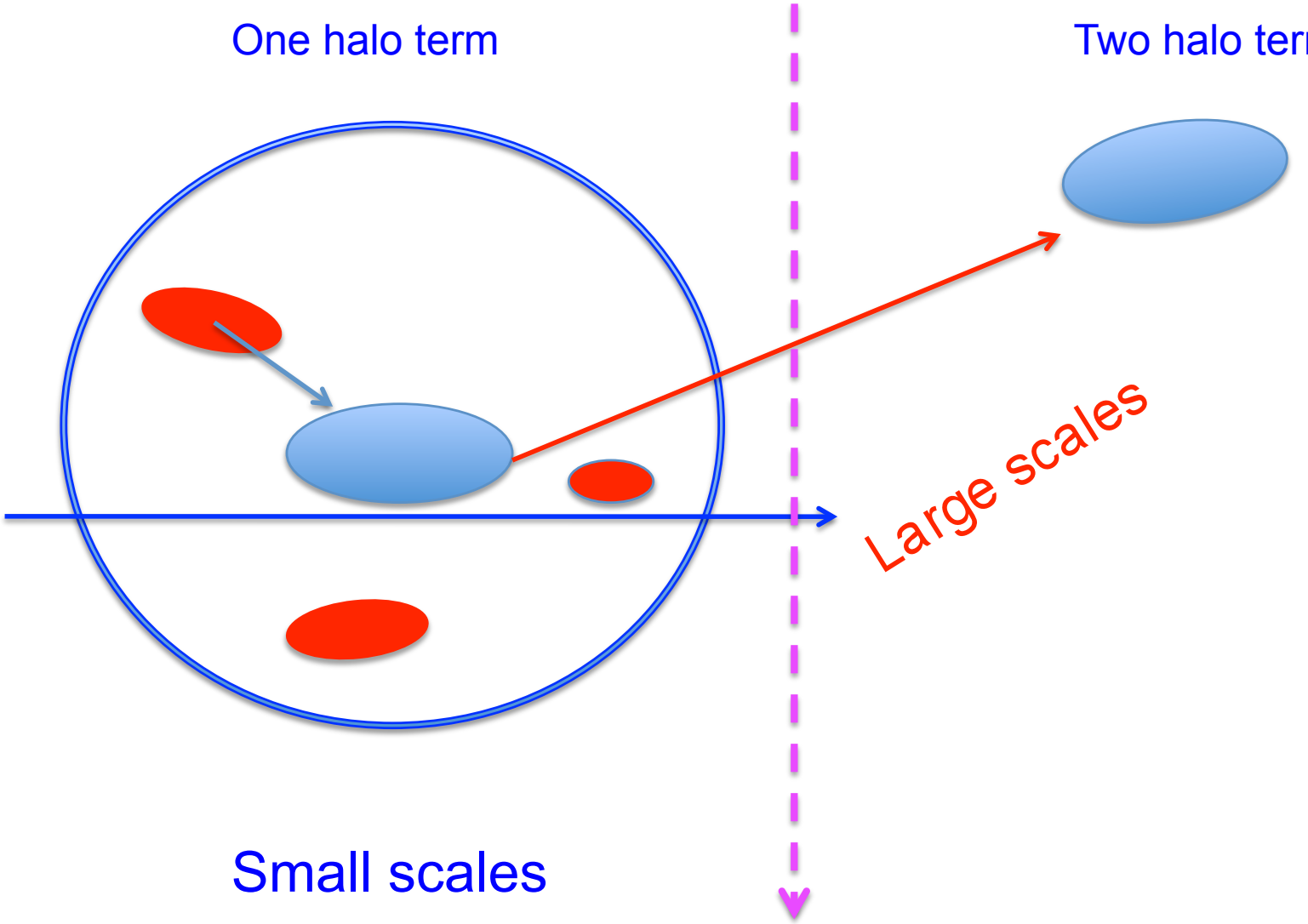
What is galaxy alignment

satellites

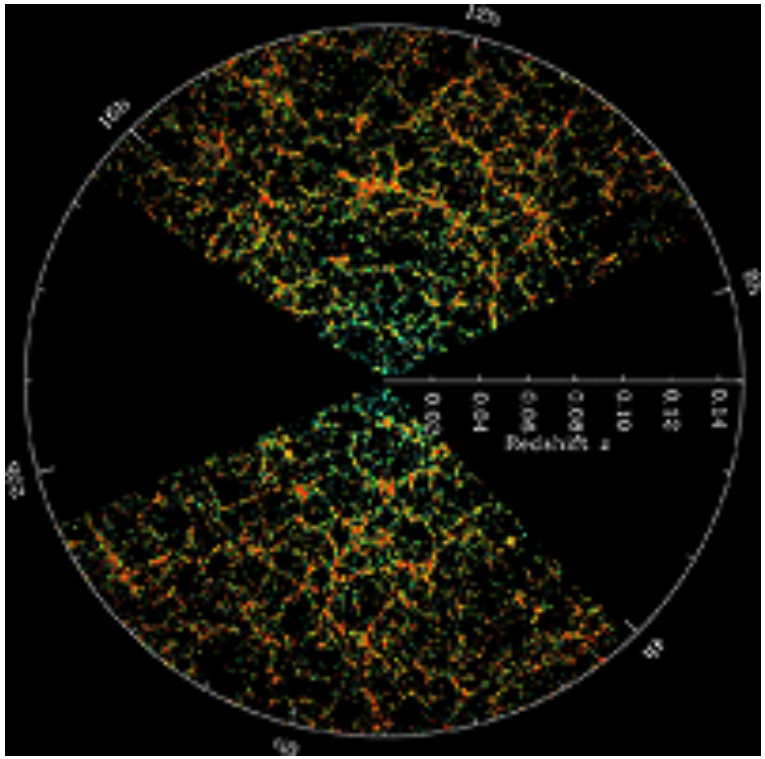
Central galaxy

Several types of galaxy alignment

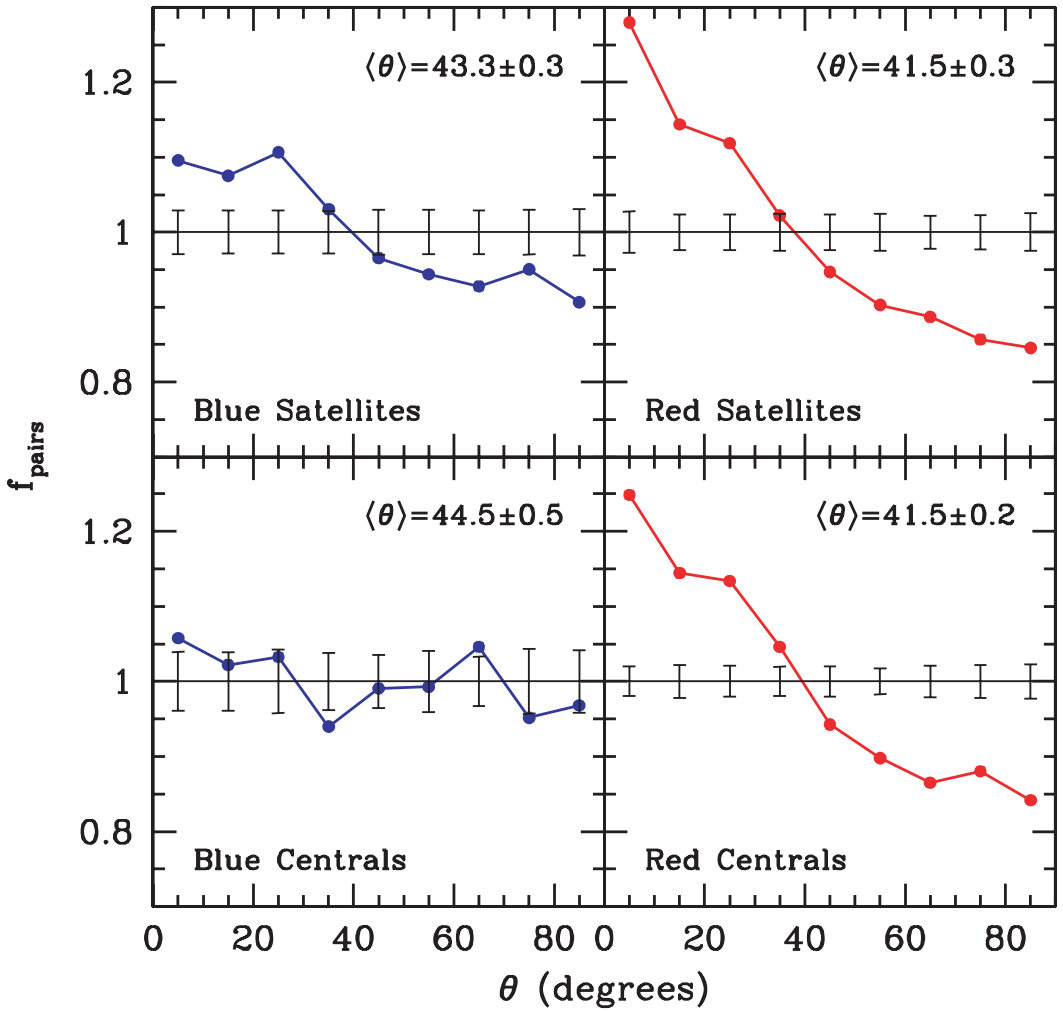


Alignment on small scale (one halo terms)

Galaxy alignment from SDSS



- Galaxies are put into Groups (Yang et al. 2006)
- The most luminous one in each group is Central galaxy, and its major axis is determined using isophoto shape
- Count the number of satellites along the major axis of central galaxies

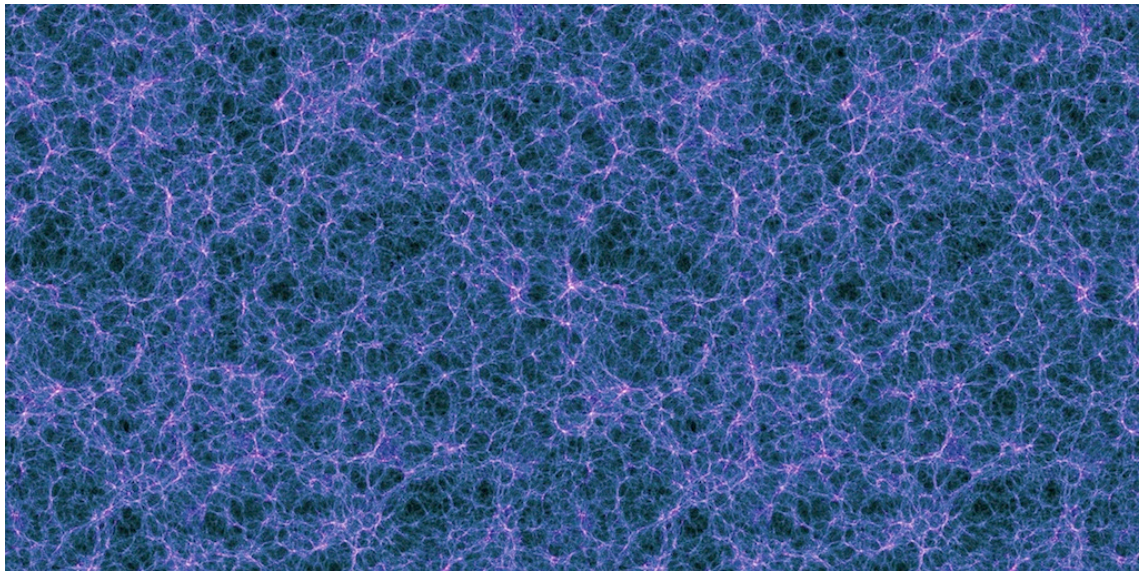


Satellites are preferred to distribute along the major axis of central galaxies

Strong alignment for red satellites and red centrals

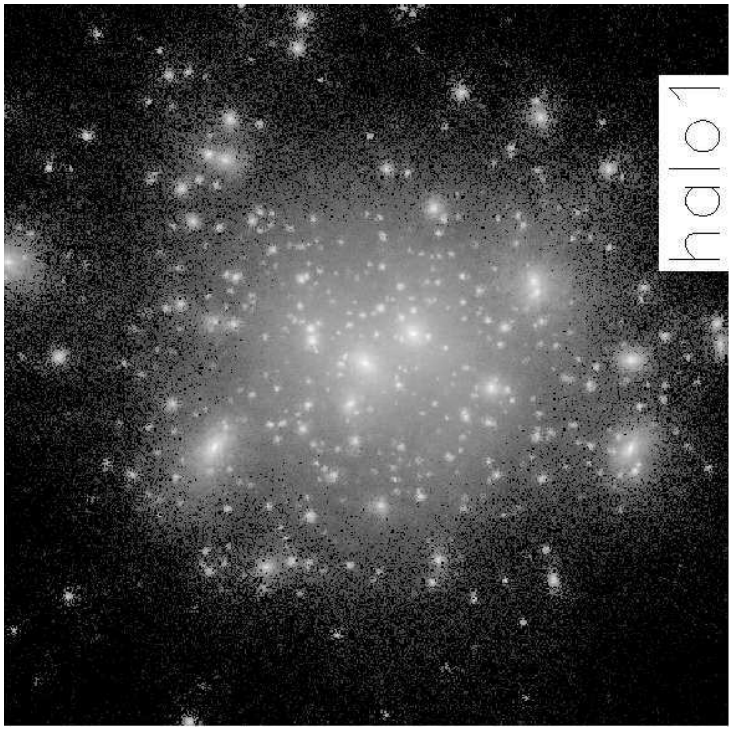
Yang X et al. 2006

Theoretical modeling (Pure N-body Simulation+Model for galaxy formation)



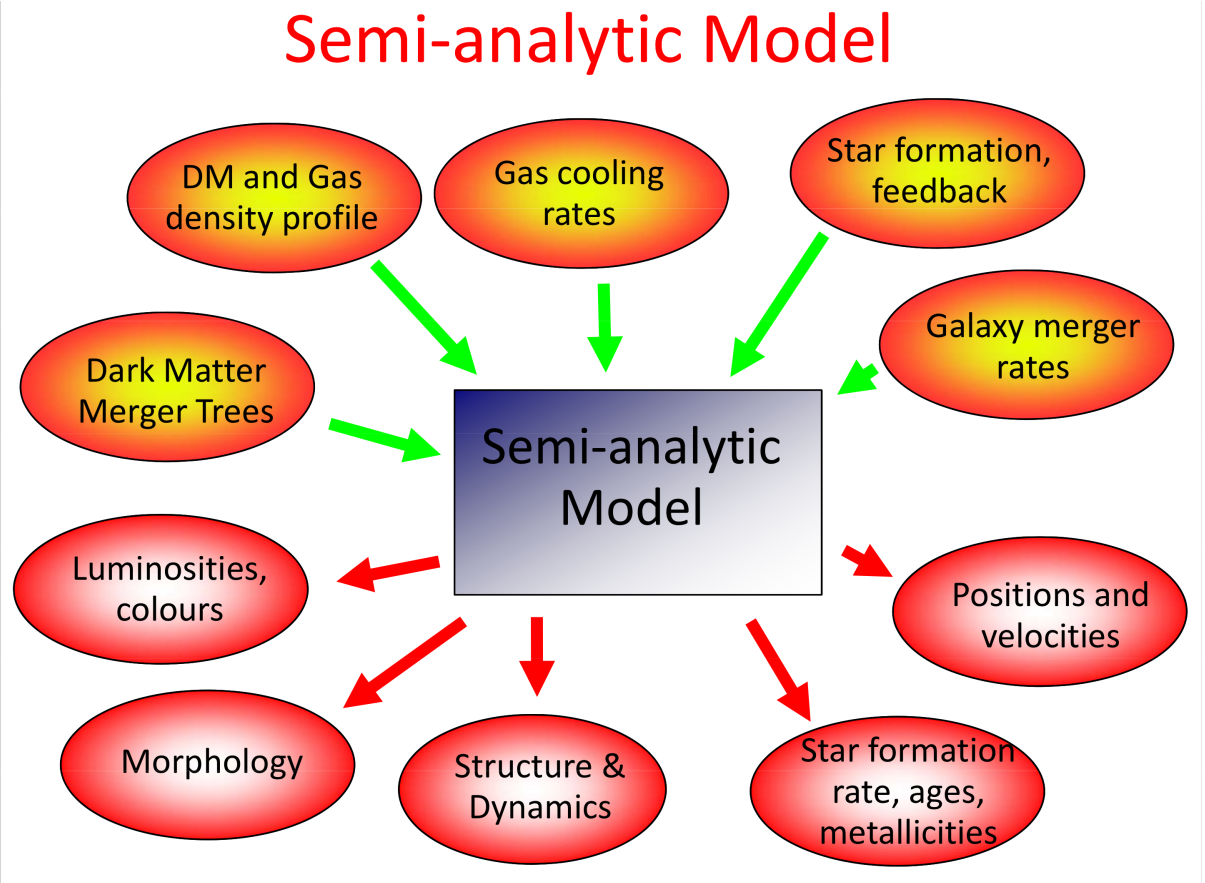
Cosmological simulation: L=100Mpc/h, N=512^3, WMAP cosmology

Jing+ 2004, Kang+ 2005



Jing et al. 2004

Semi-analytical model for galaxy formation



Galaxy position & Velocity

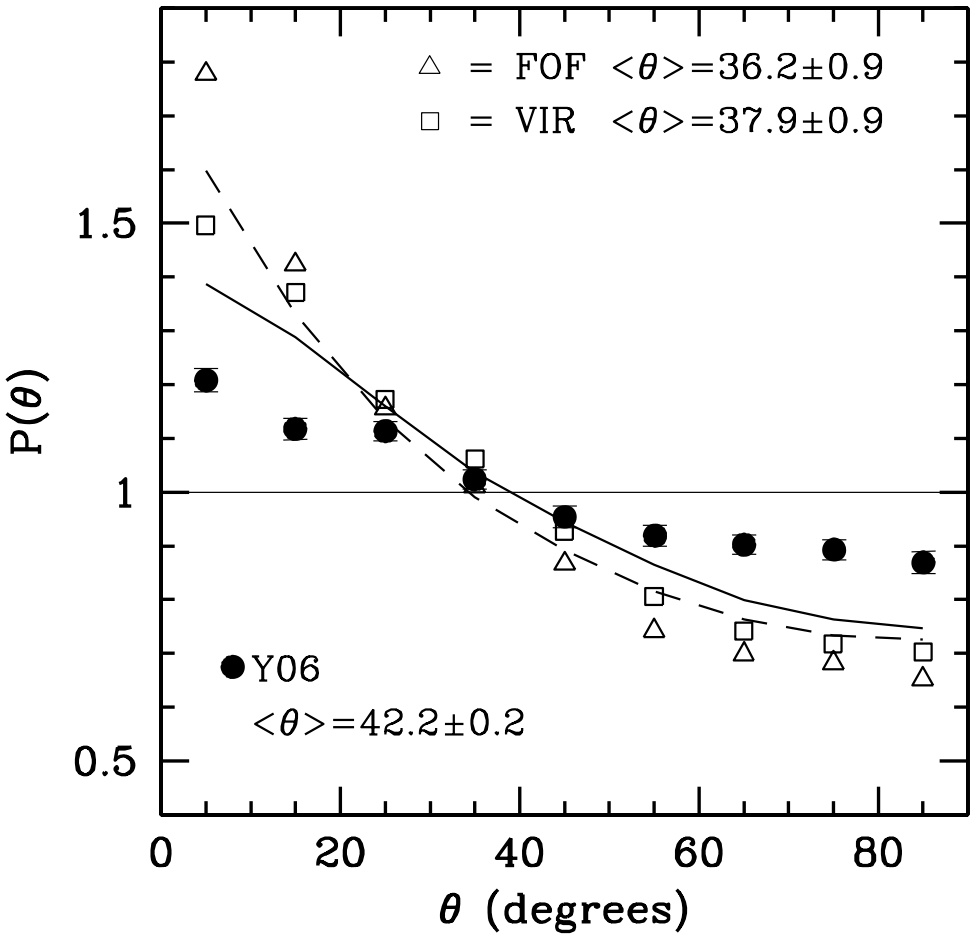
Galaxy luminosity, color, star formation rate etc

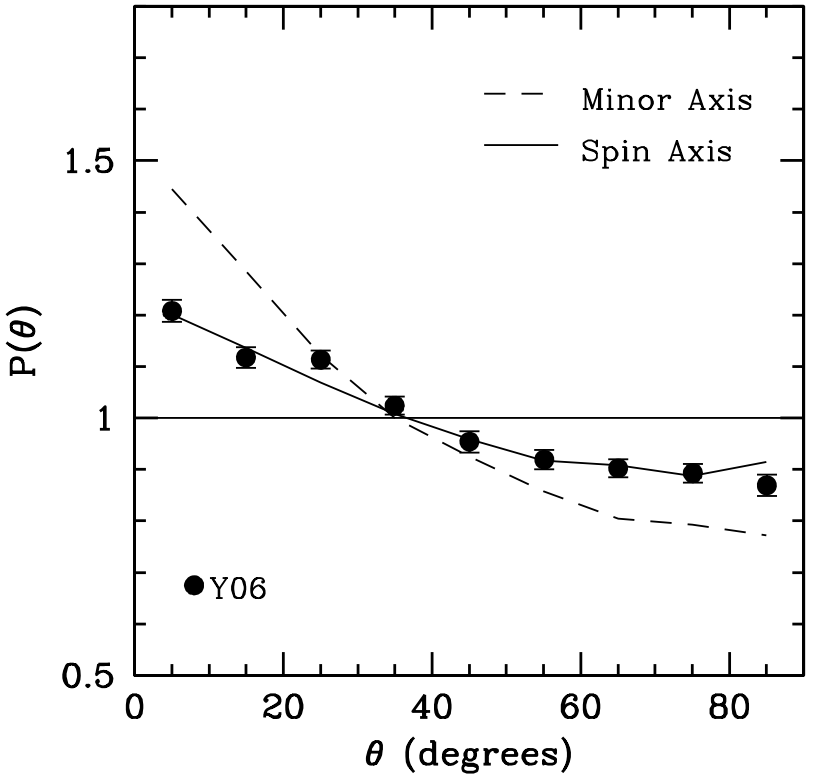
Kang et al. 2005,2006,2008,2010,2012

If central galaxy follows the whole DM halo shape

Central galaxy follows major axis of halo

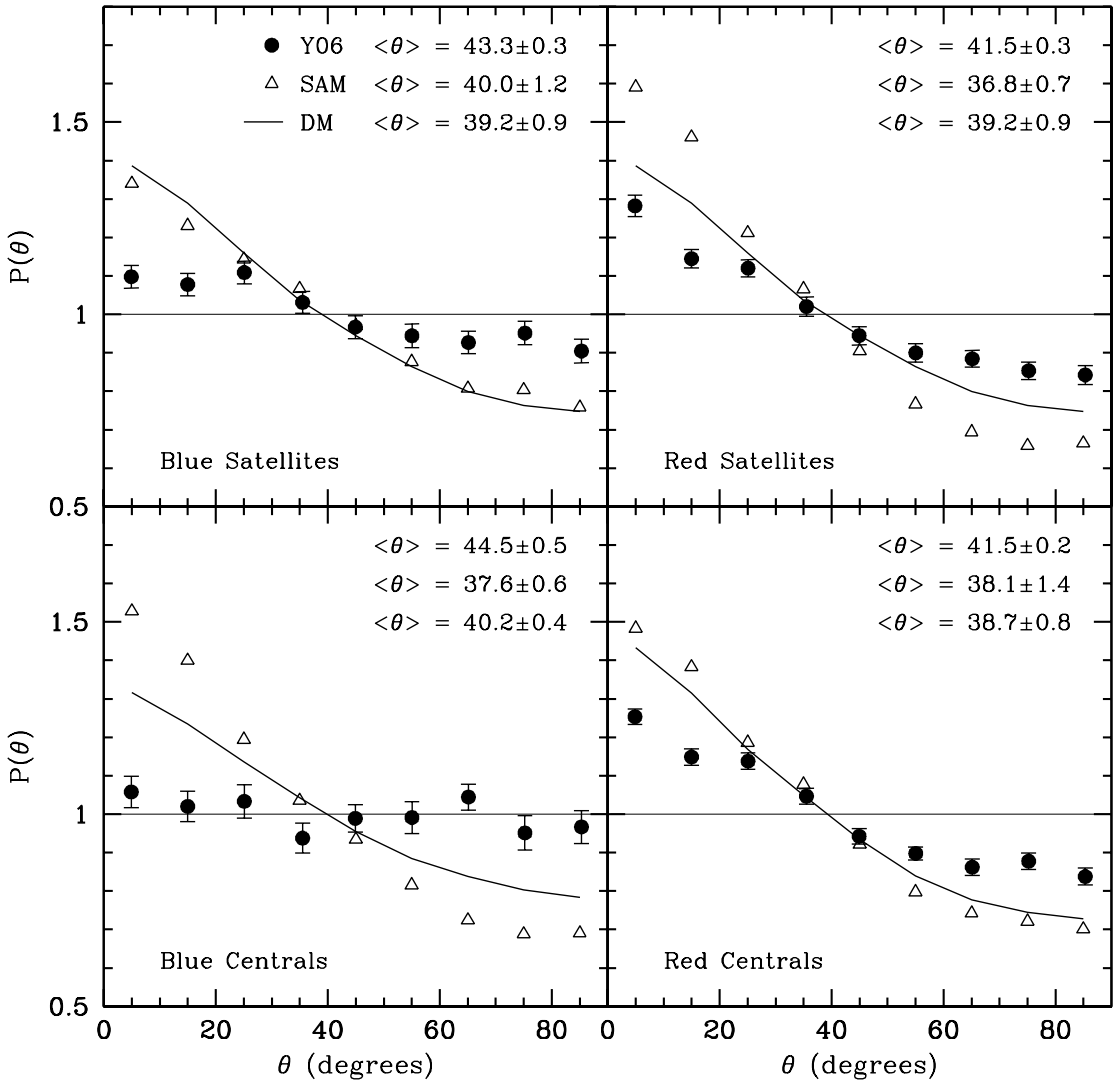
Follow minor or Spin





Kang+ 2007

color dependence

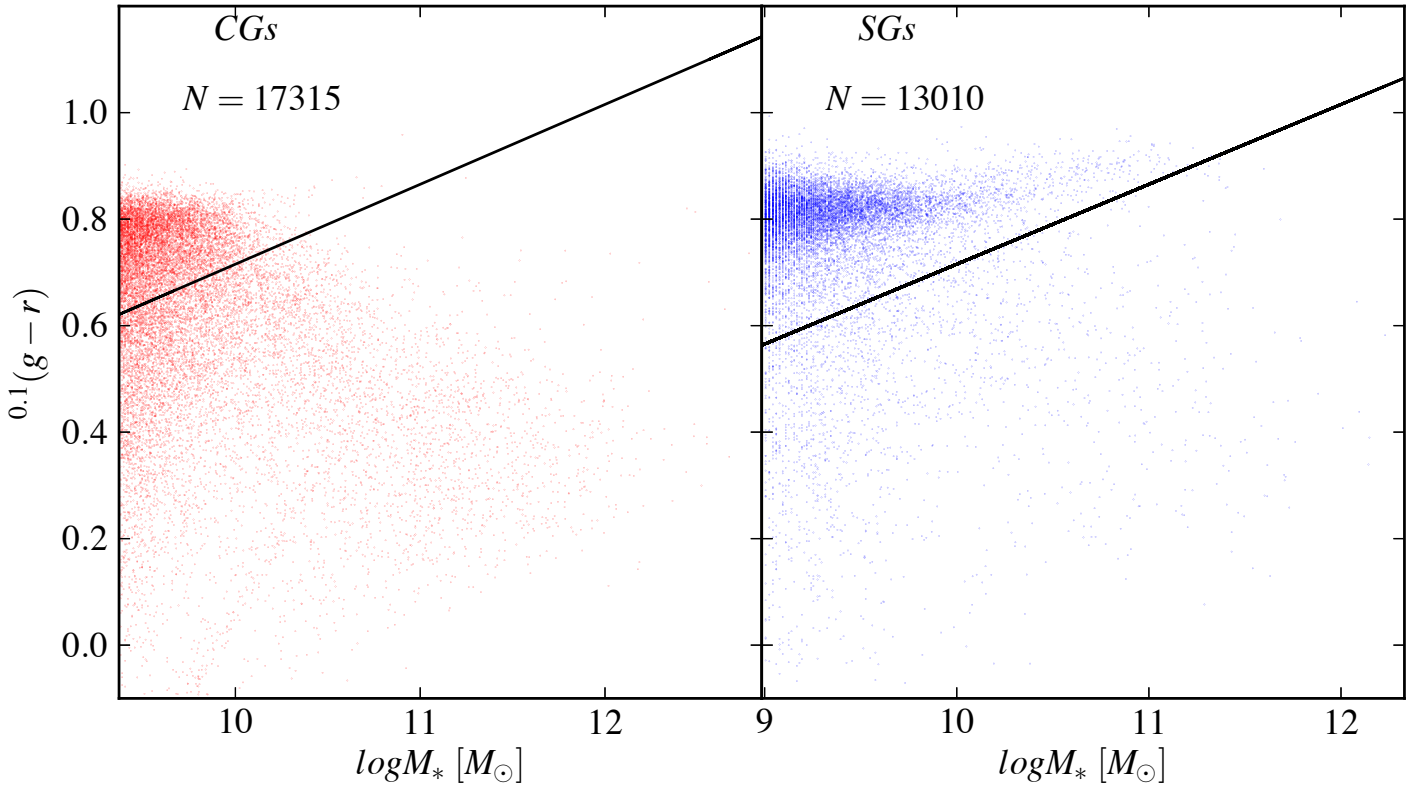


Kang et al. 2007, MNRAS

Red satellites have stronger alignment than blue and DM particles: most of them are in inner halo, where the halo shape is more prolate

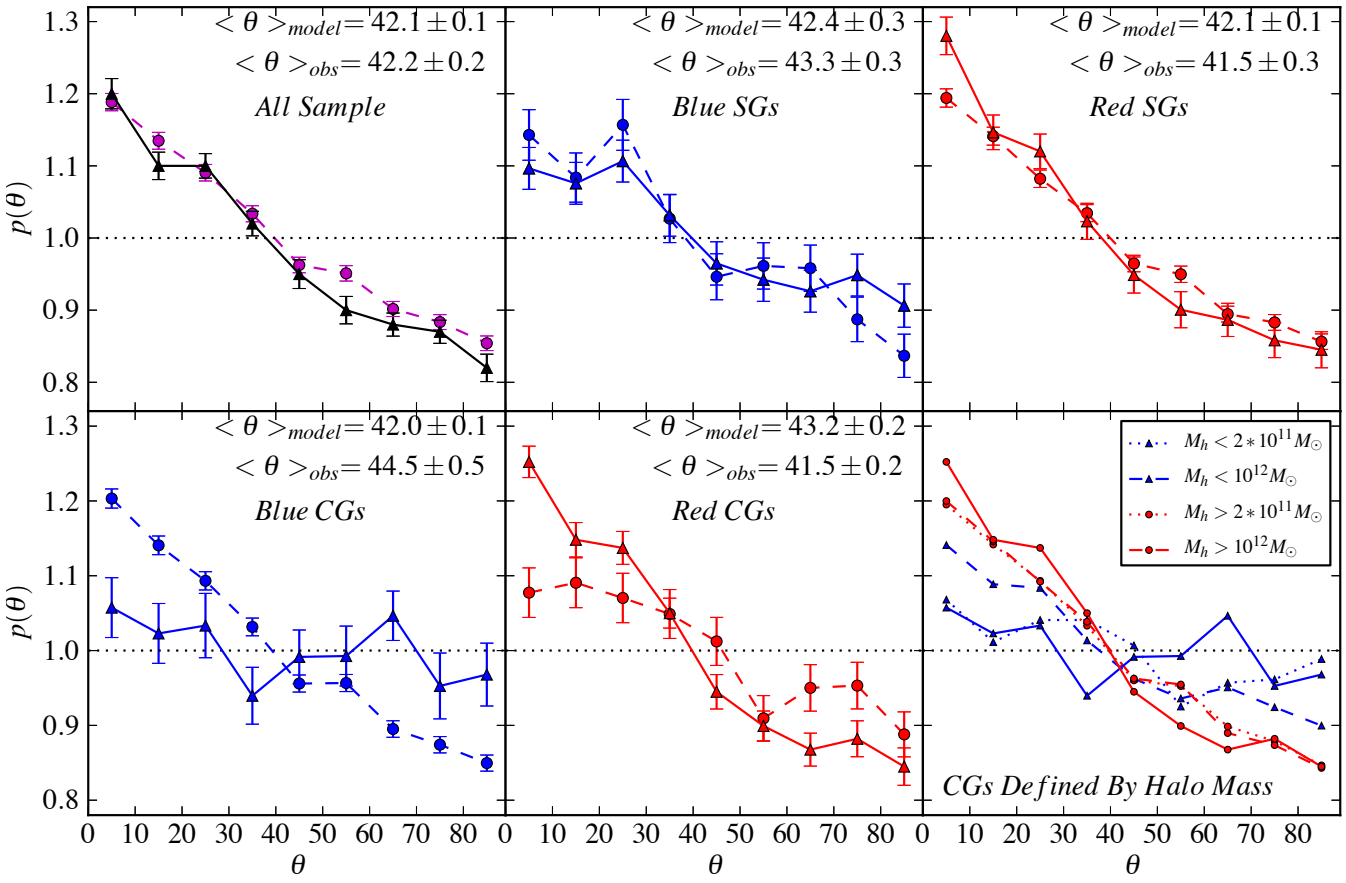
No dependence on color of central galaxies

Using Hydro-dynamical simulations: gas cooling, star formation, supernova feedback (Gadget-2)



Lin+ 2014, In preparation

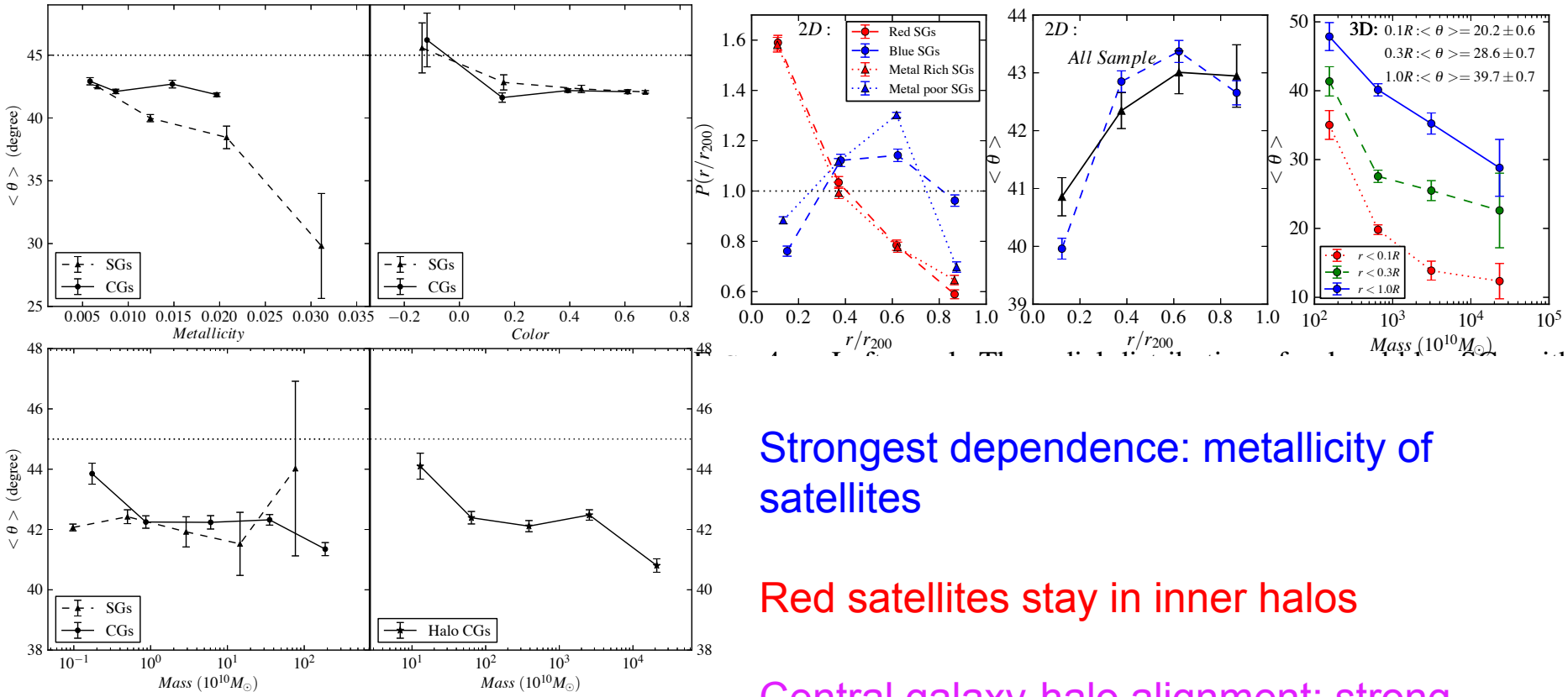
Galaxy shape is obtained from Hydro-simulation



Lin+ 2014, in preparation

- Alignment: agree with data
- Have dependence on satellite color
- Blue centrals have too strong alignment
- Alignment has halo mass dependence

Predictions from simulation



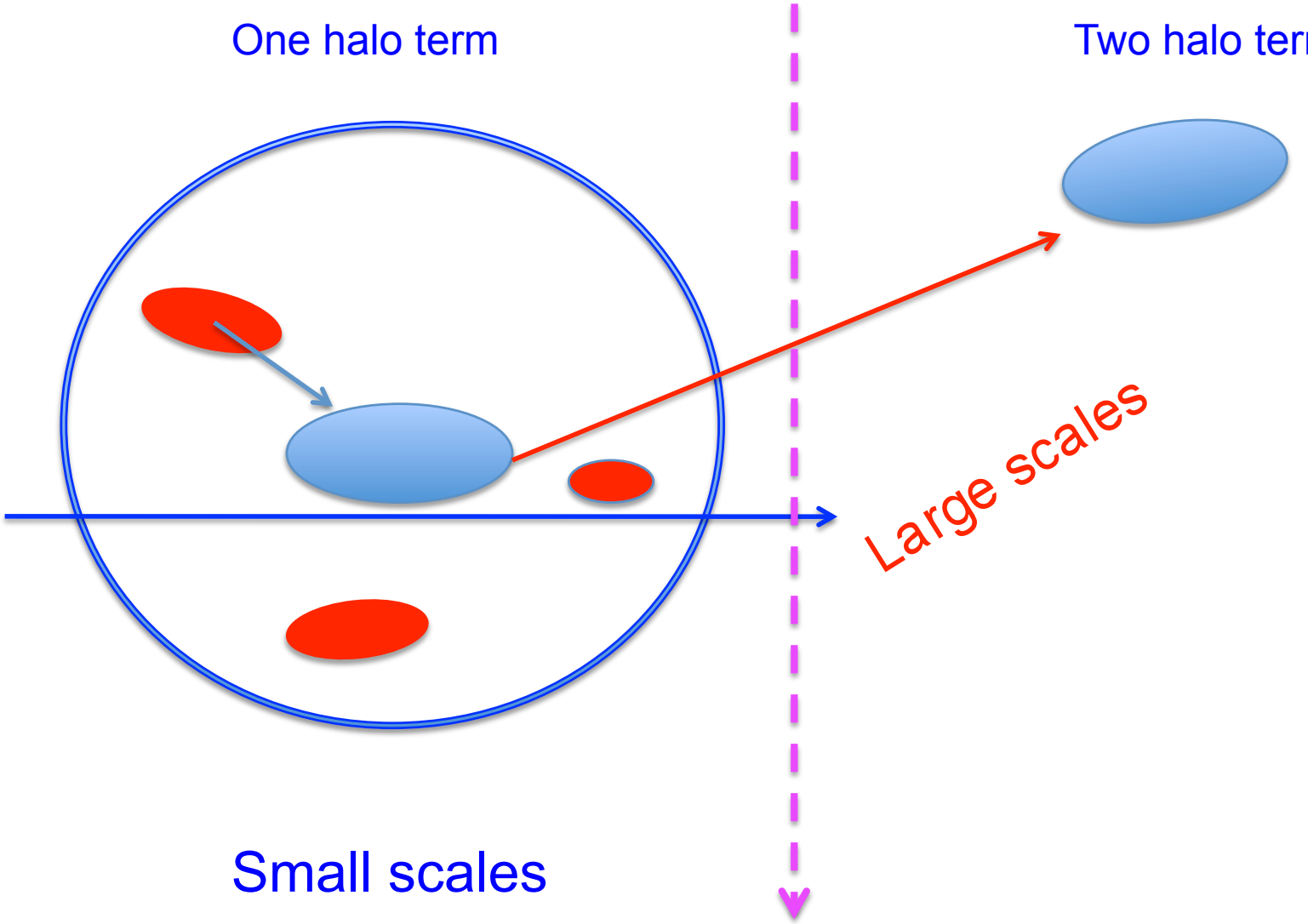
Strongest dependence: metallicity of satellites

Red satellites stay in inner halos

Central galaxy-halo alignment: strong correlated with inner halo, also increase with halo mass

Lin+ 2014, in preparation

Alignment on large scales (2-halo)



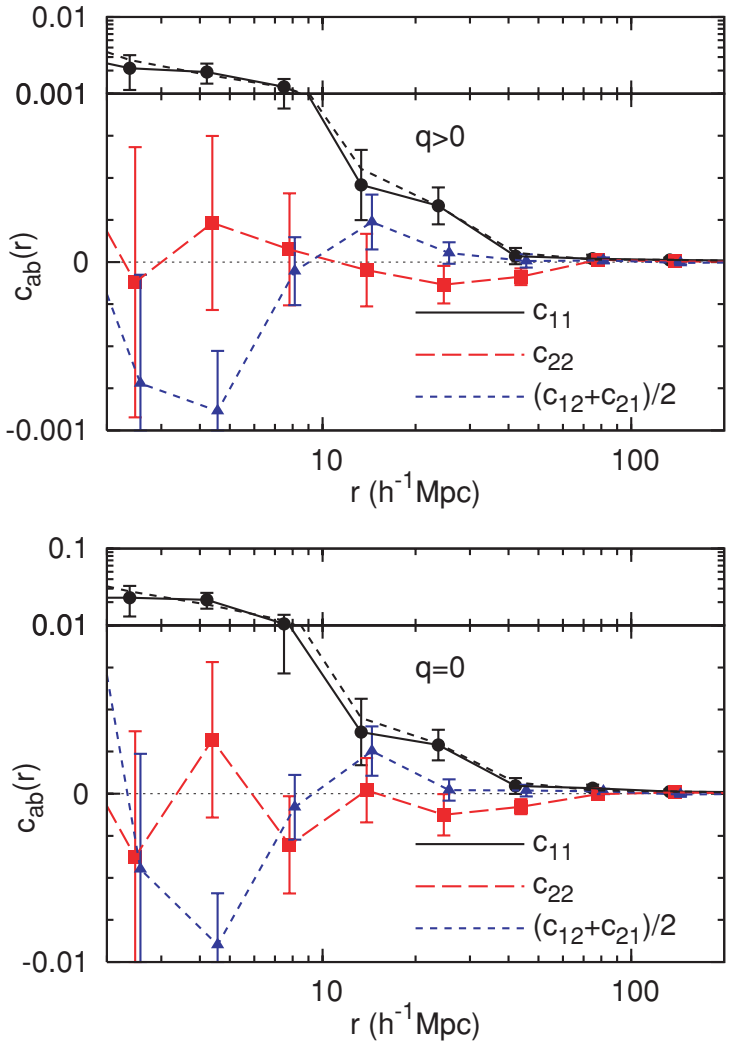
Alignment on large scales

$$\begin{pmatrix} e_1 \\ e_2 \end{pmatrix} = \frac{1-q^2}{1+q^2} \begin{pmatrix} \cos 2\beta \\ \sin 2\beta \end{pmatrix}$$

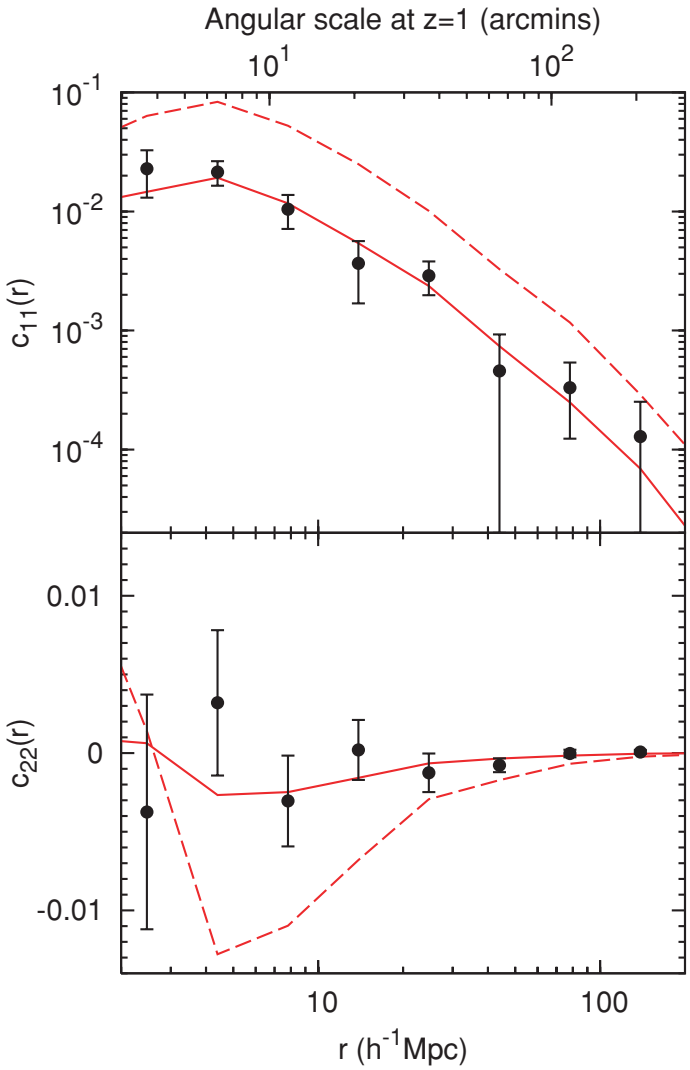
$$c_{ab}(r) = \langle e_a(\mathbf{x}) e_b(\mathbf{x}+\mathbf{r}) \rangle$$

Teppi & Jing 2009

Ellipticity correlation for LRGs from SDSS



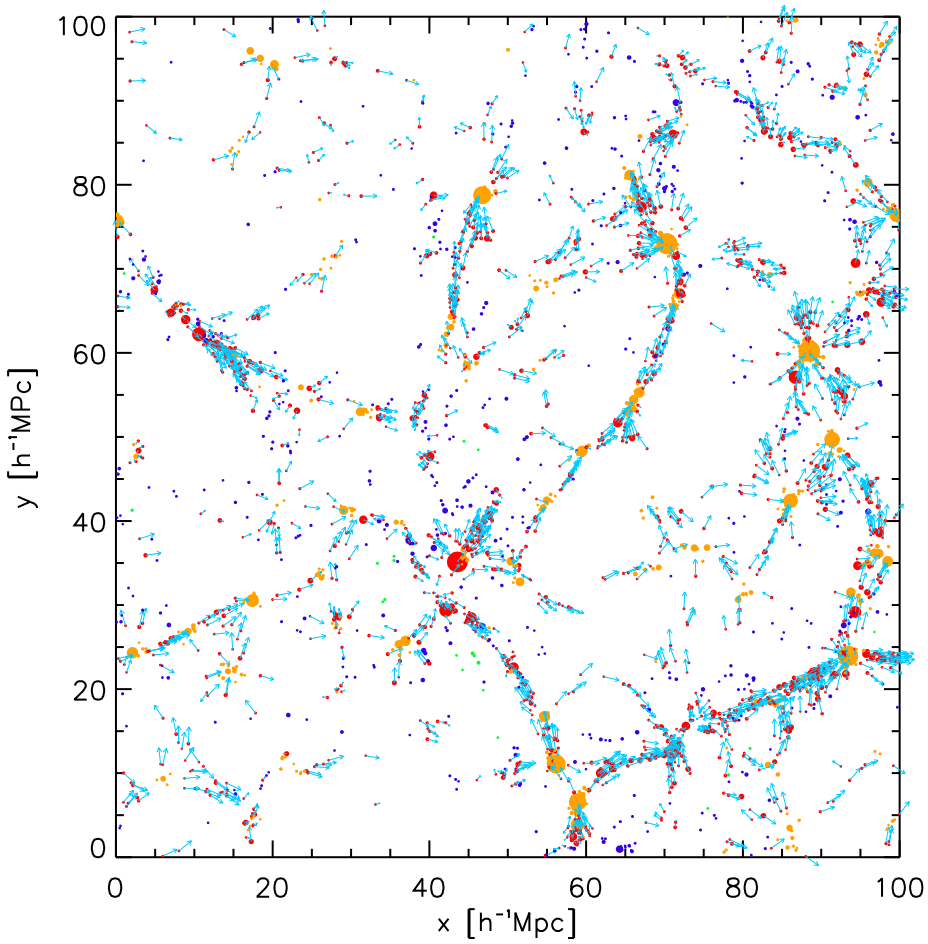
Prediction from Simulation



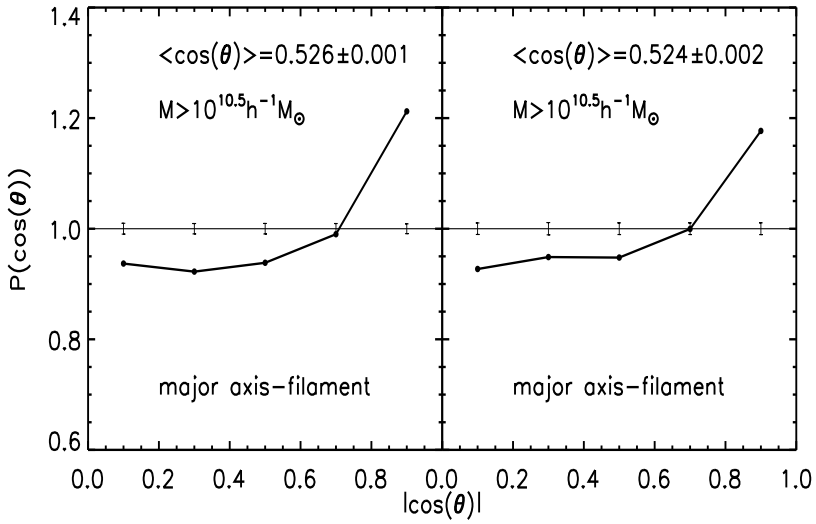
Mis-alignment between central galaxy and DM halo is about 35 degree

Teppi & Jing 2009

Where is the large-scale alignment from?

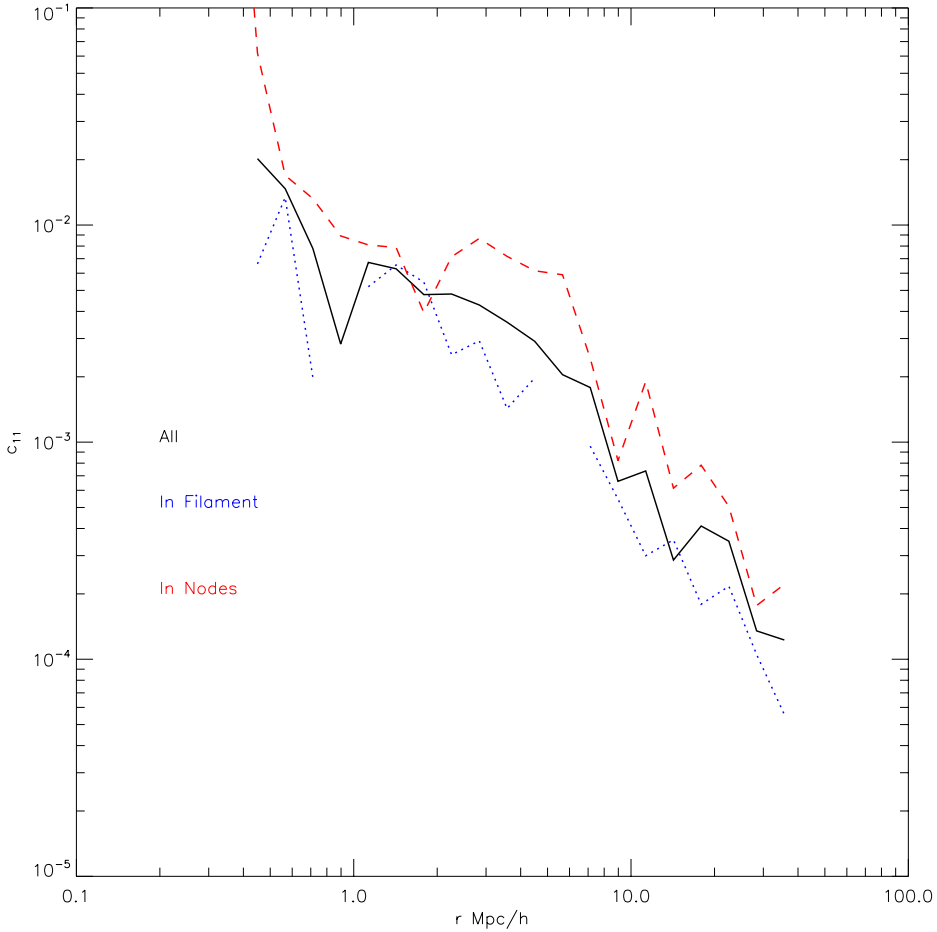


Halo major axis-Filament correlation



Zhang et al. 2009

Is the alignment dominated by halo in filament or nodes?



Large-scale alignment dominated by halos in nodes

Present alignment is set in the past

Kang X, in preparation

Summary (take home message)

- Galaxy alignment on small scale is mainly from the non-spherical/tri-axial nature of DM halo
- Central galaxy follows better the shape of DM in inner region, and it increases with halo mass
- Large scale alignment is mainly from halos in Nodes