Intrinsic ellipticity correlation of luminous red galaxies on large scales

Berkeley Cosmology Seminar

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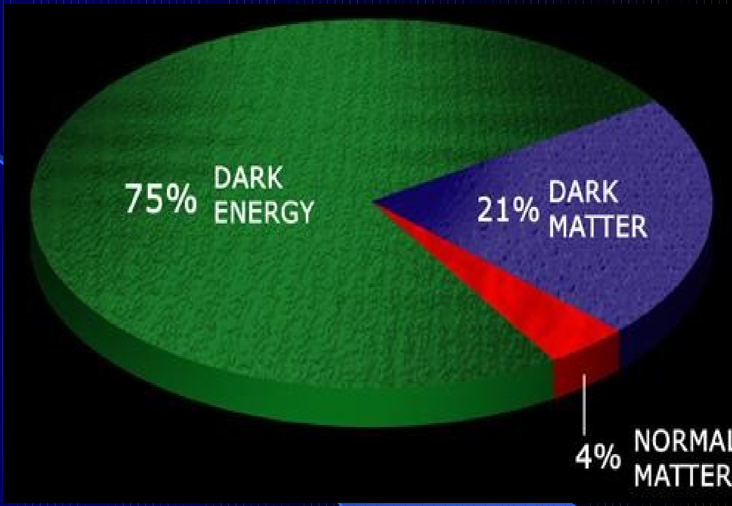
References:

Okumura, Jing, & Li (2009) ApJ, 694, 214

Okumura & Jing (2009) ApJL, 694, L83

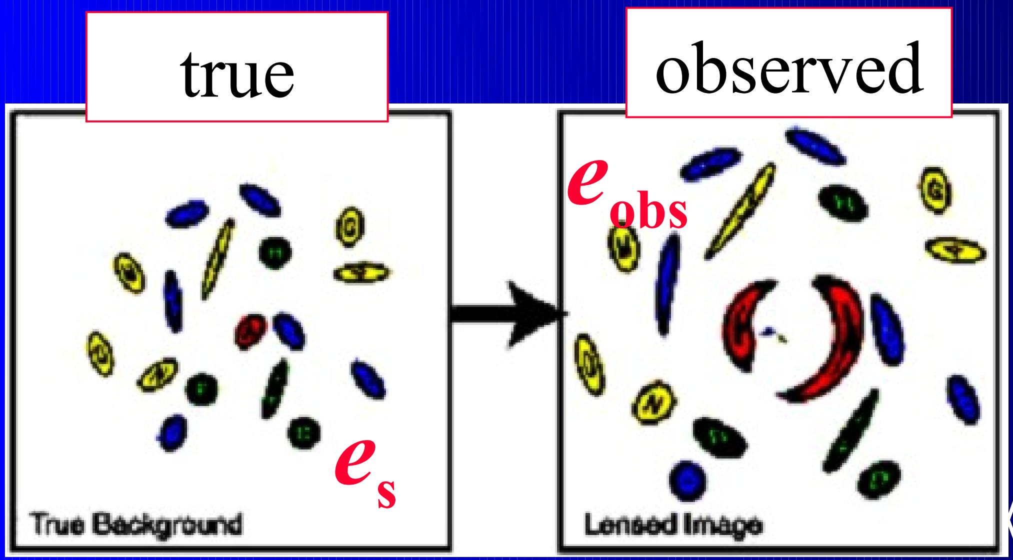
Introduction (1)



- Precision Cosmology
  - CMB, Large-scale structure, Weak lensing, Type Ia Supernova, Cluster number count, …
- What is dark energy?
  - Cosmological constant ($w = -1$)? or modified gravity? or else?
- Systematic effects in weak lensing surveys
  - Instrumental
    - Systematic photo-z errors
  - Physical
    - Non-linear effects
    - ***Intrinsic alignments of galaxies***

Introduction (2)

- Observable in weak lensing surveys
  - Ellipticity of galaxies e_{obs}



Gravitational shear (G)

Intrinsic ellipticity (I)

$$e_{obs} = \gamma + e_s$$

$$\langle e_{obs} \rangle = \langle \gamma \rangle$$

Tidal field

$$\langle e_{obs} e_{obs} \rangle = \langle \gamma\gamma \rangle + \langle e_s e_s \rangle$$

Intrinsic ellipticity – ellipticity (II) correlation function

Croft & Metzler (2000), Heavens et al (2000)

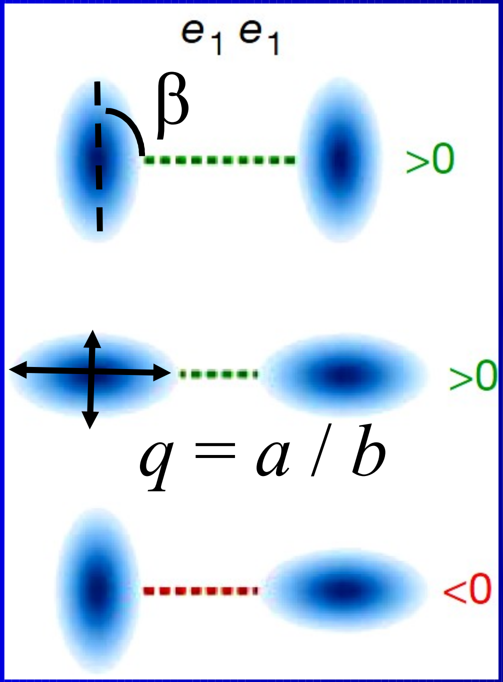
Observation of II correlation (1)

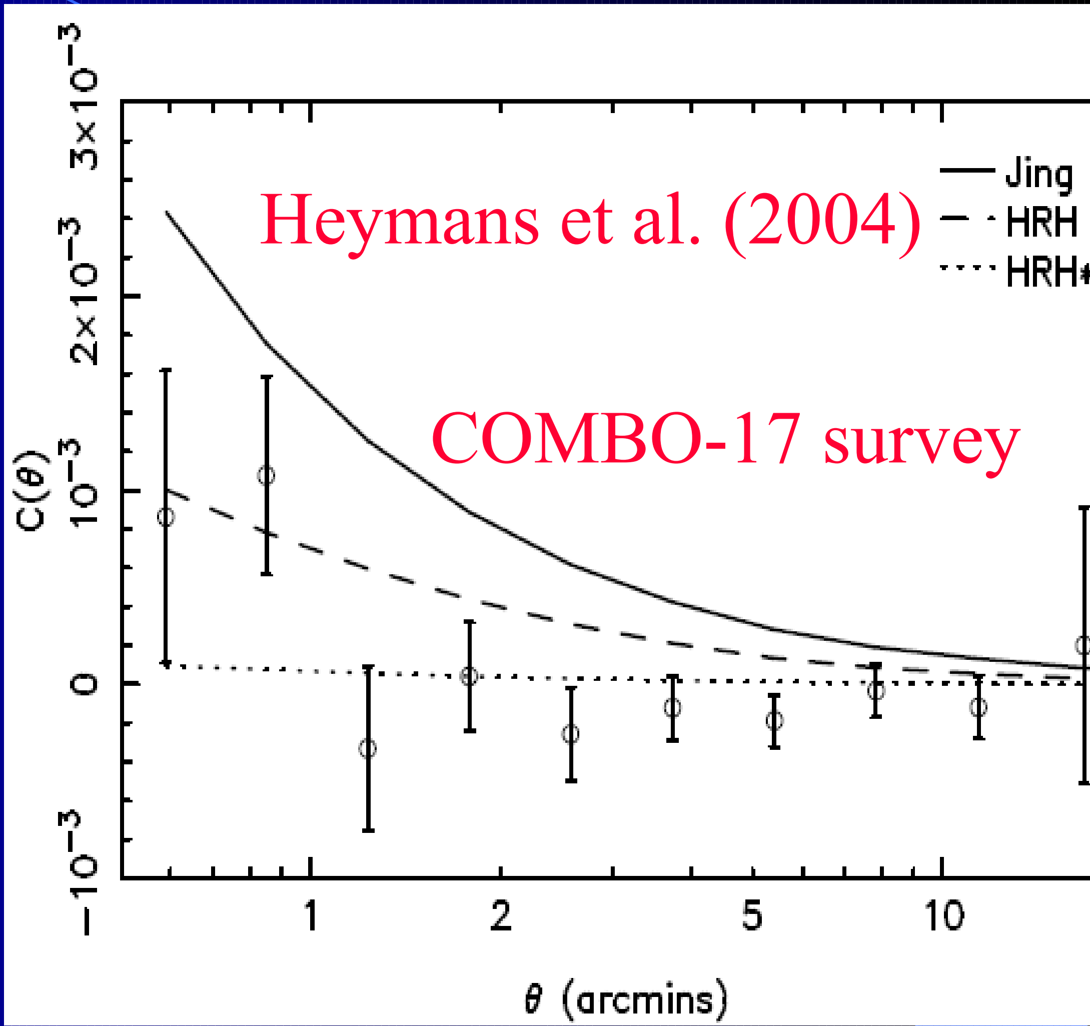
- Ellipticity

$$e_1 = \frac{1-q^2}{1+q^2}\cos(2\beta) = \cos(2\beta$$

- II correlation function

$$c_{11}(r) = \langle e_1(\mathbf{x}) e_1(\mathbf{x}+\mathbf{r}) \rangle$$





→ less than 2% contamination!

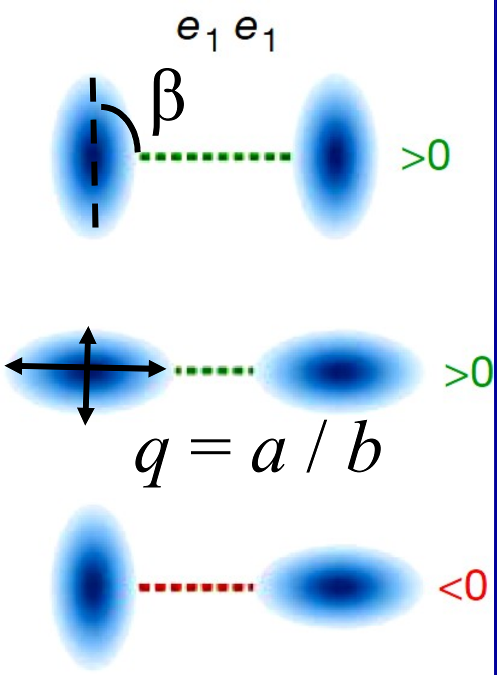
Observation of II correlation (2)

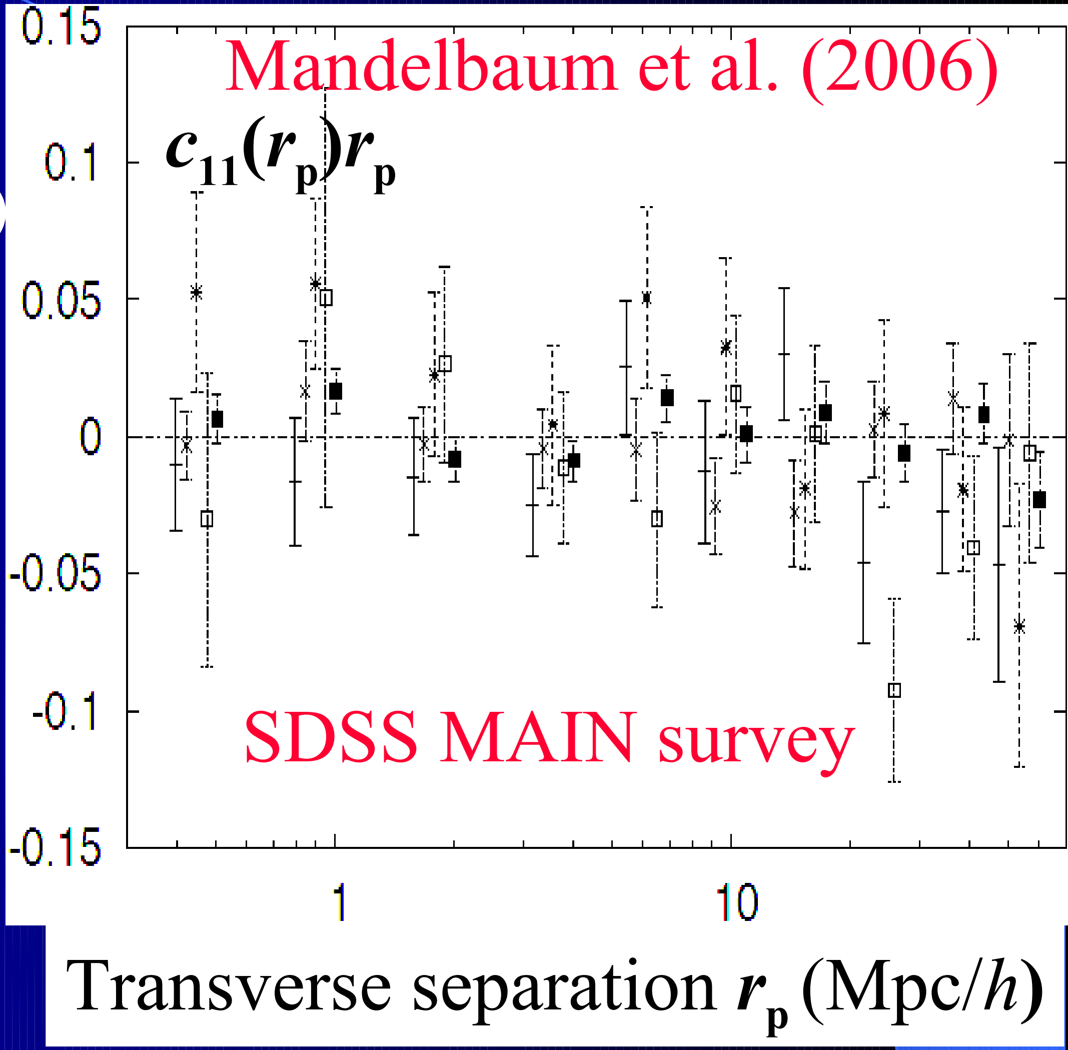
- Ellipticity

$$e_1 = \frac{1-q^2}{1+q^2}\cos(2\beta) = \cos(2\beta)$$

- II correlation function

$$c_{11}(r) = \langle e_1(\mathbf{x}) e_1(\mathbf{x}+\mathbf{r}) \rangle$$





→no detection
(consistent with Heymans+)

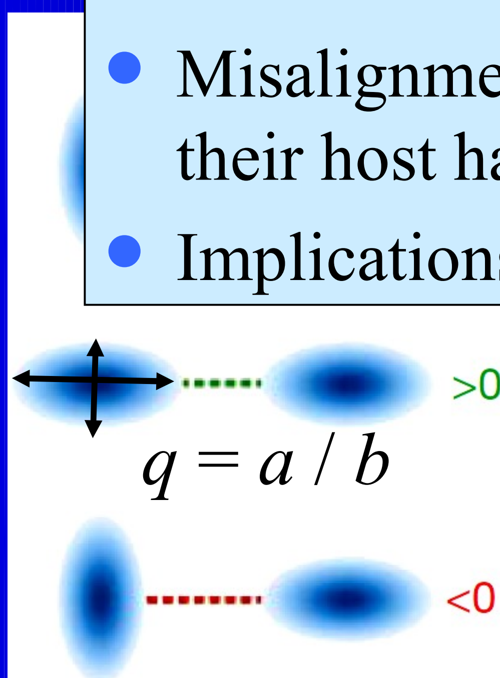
Observation of II correlation (2)

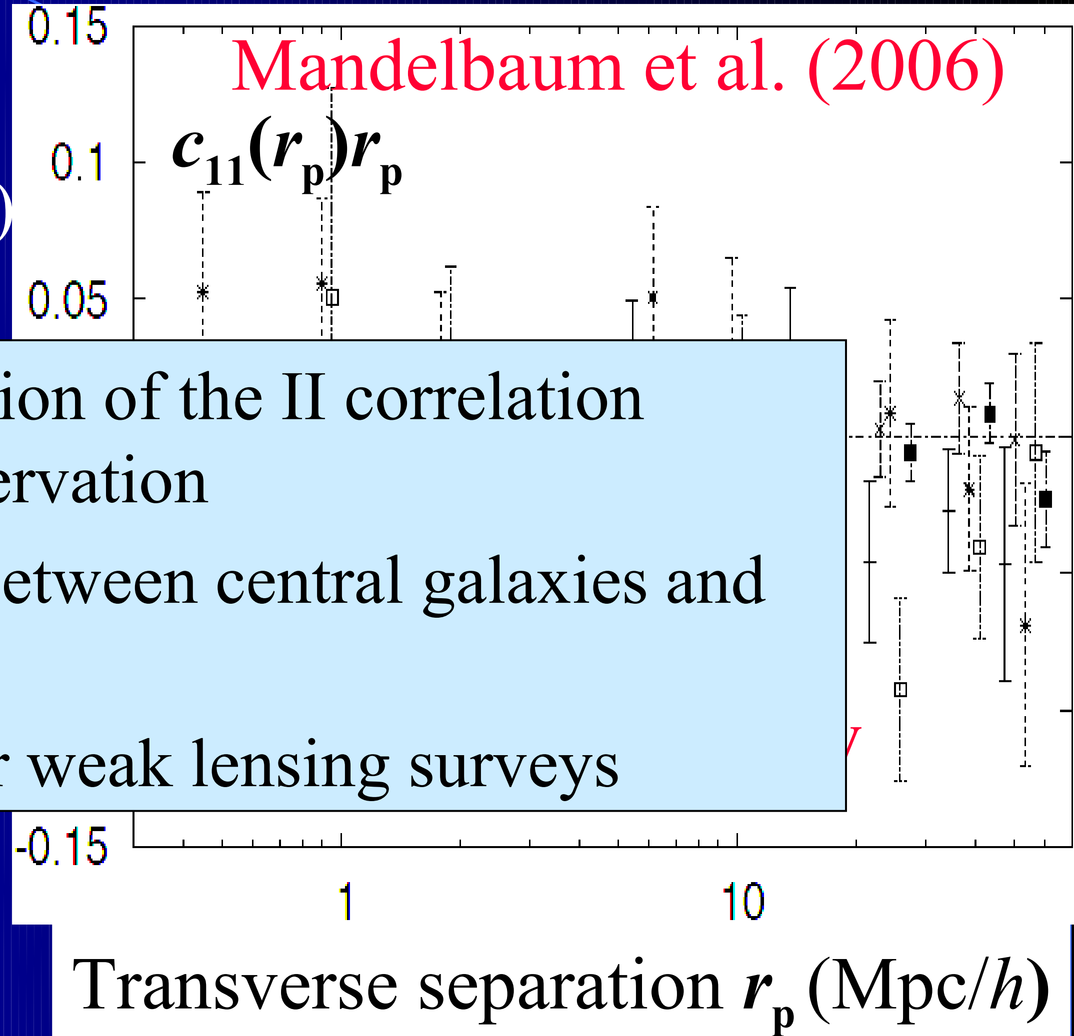
- Ellipticity

$$e_1 = \frac{1 - q^2}{1 + q^2}\cos(2\beta) = \cos(2\beta)$$

- II corre

$$c_{11}(r) = \langle e_1($$





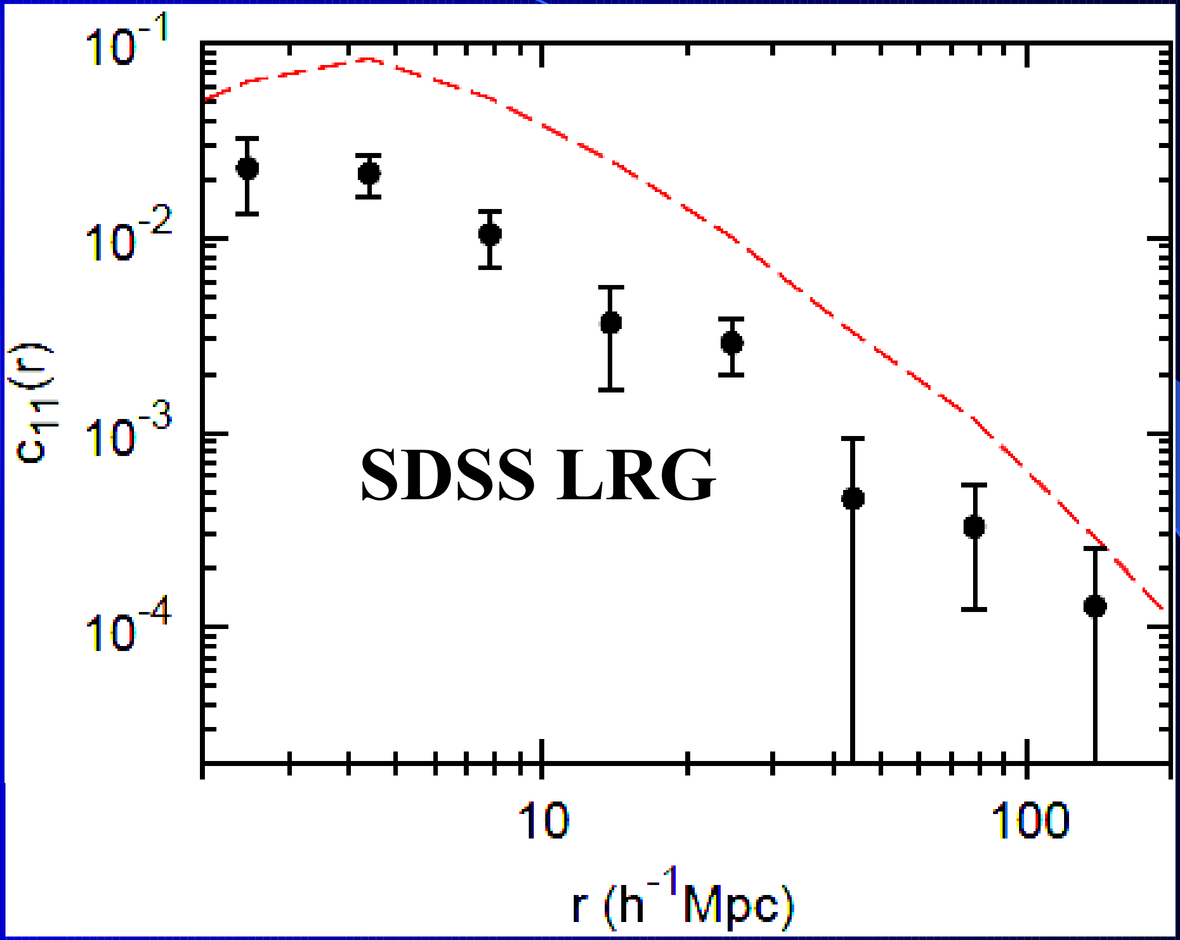
- Accurate detection of the II correlation function in observation
- Misalignment between central galaxies and their host halos
- Implications for weak lensing surveys

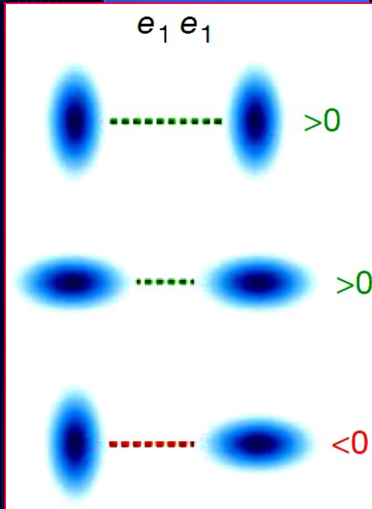
→no detection
(consistent with Heymans+)

Luminous red galaxies (LRG) from the SDSS Data Release 6

- 83,700 spectroscopic LRG sample
- Properties of LRGs
  - Exists at broader redshift range, $0.16 < z < 0.47$
  - Giant ellipticals (not contaminated by spirals)
  - Almost all the LRGs are central galaxies (~ 95%)
  - LRGs preferentially reside in massive halos
- → Much higher II correlation signal is expected

The II correlation function of SDSS LRGs



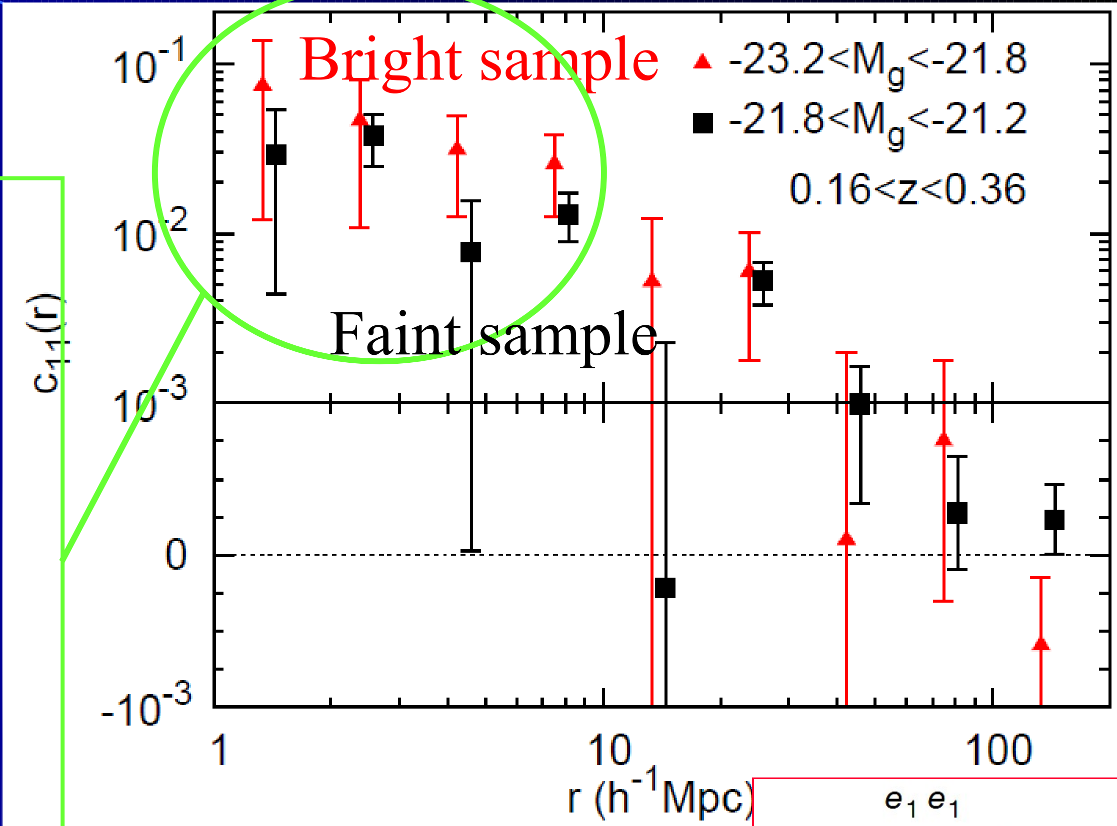


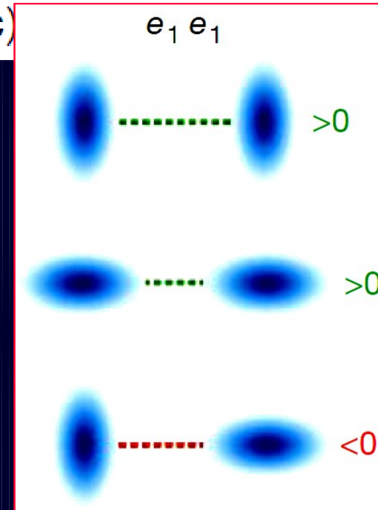
- Clear detection up to ~ $30h^{-1}$Mpc

The II correlation function of SDSS LRGs

Luminosity dependence

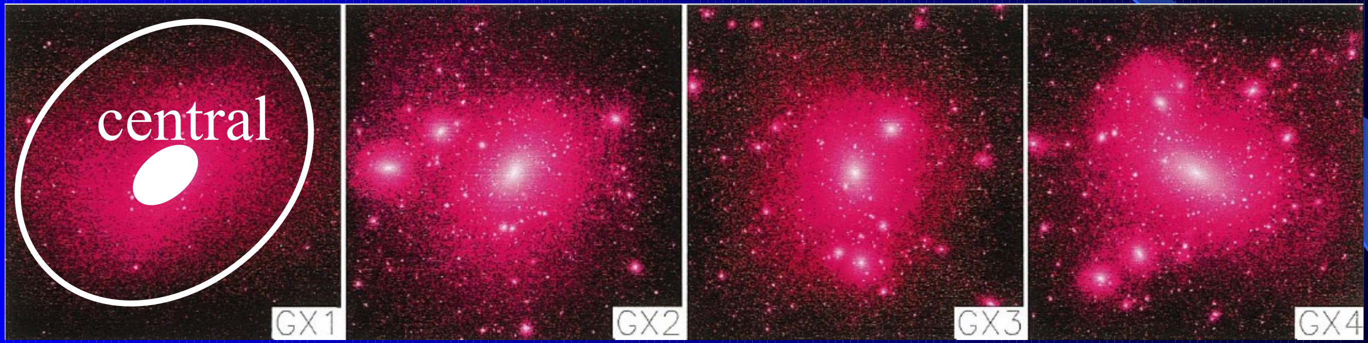
- Stronger correlations can be seen in the brighter sample although the error bars are large.
- Brighter LRGs tend to reside in more massive halos.





Modeling the II correlation

- Cosmological *N*-body simulation (Jing et al. 2007)
  - 1024^3 particles, L_{box}=1200Mpc/h → $m_p=1.2\times10^{11}M_{sun}/h$

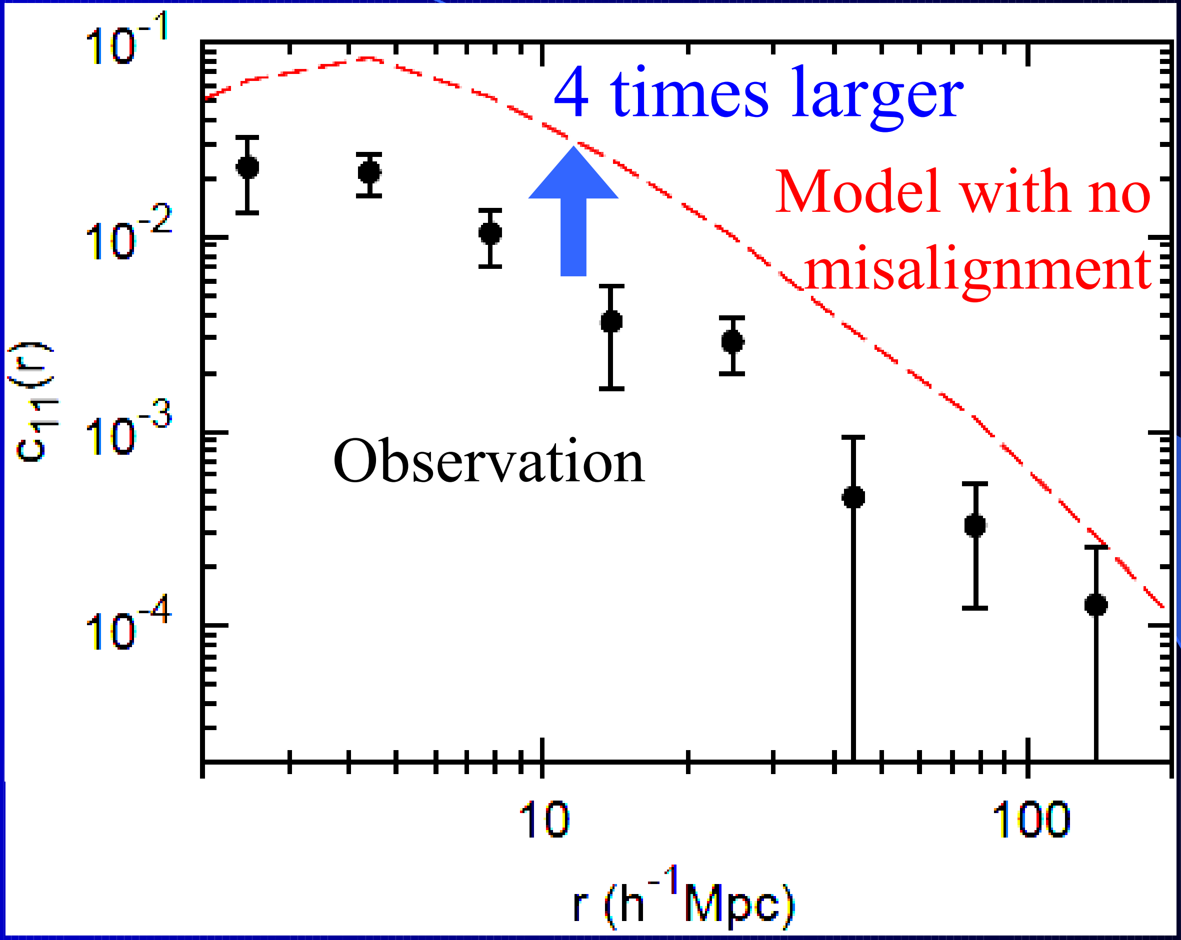


Halo occupation distribution for LRGs

$$N_{LRG}(M)=N_{cen}(M)+N_{sat}(M)$$

- Mock LRG catalog
  - The II correlation function for central LRGs can be modeled once the relationship between ellipticities of central LRGs and of their host halos is assumed.

Comparison of observation with model



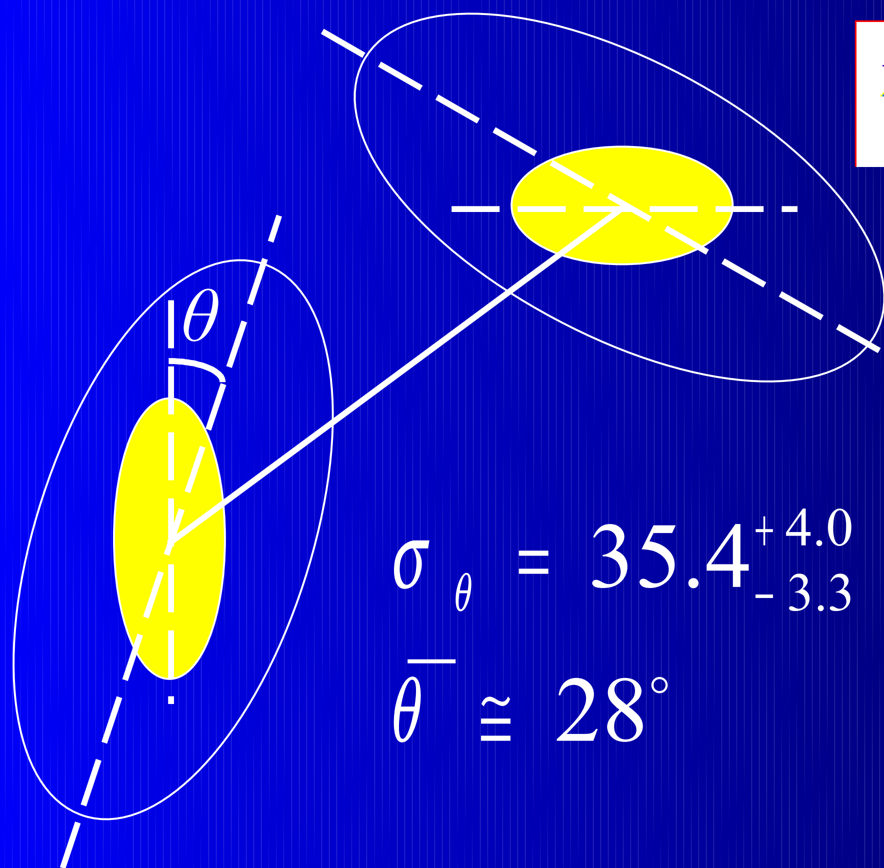
- We will model the II correlation by taking into account the misalignment between central LRGs and their host halos.

Misalignment between central LRGs and their host halos

- Misalignment angle parameter σ_θ
  - Assumption of Gaussian PDF

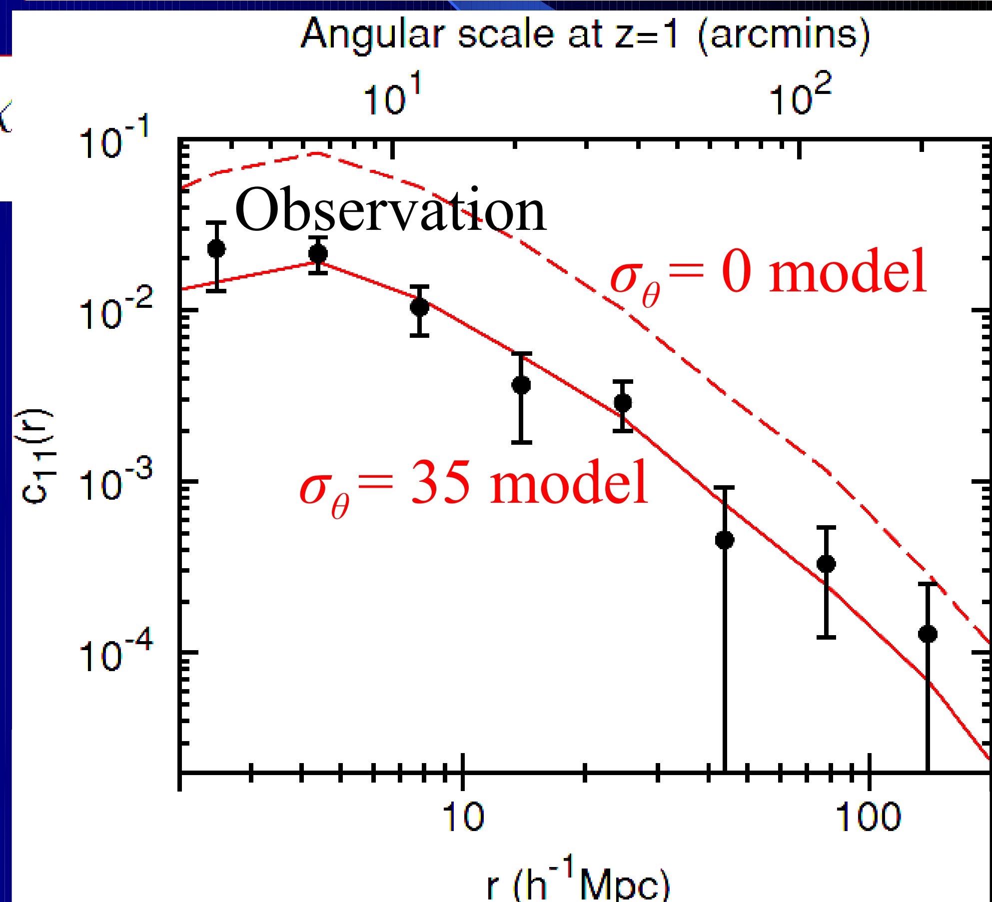
$$f(\theta;\sigma_\theta)d\theta = \frac{1}{\sqrt{2\pi}\sigma_\theta}\exp\left[-\frac{1}{2}\left(\frac{\theta}{\sigma_\theta}\right)^2\right]d\theta$$

χ



$$\sigma_\theta = 35.4^{+4.0}_{-3.3}$$

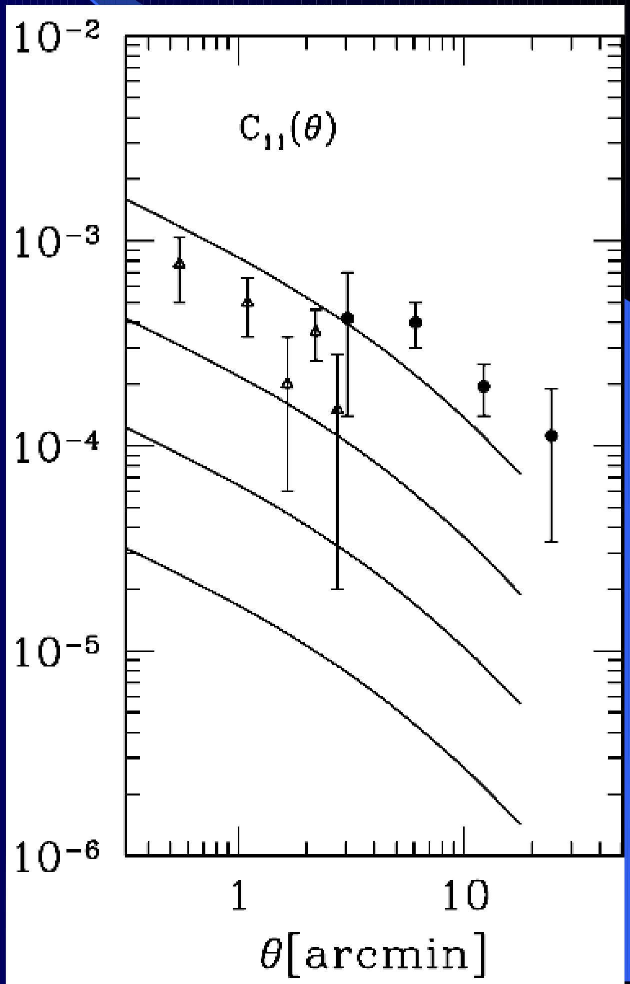
$$\bar{\theta} \cong 28^\circ$$



Implications for weak lensing surveys

- An example
  - CFHTLS weak lensing survey ($z_s \sim 1$ and R_{AB}=24.5). (Fu+)
  - Central galaxies in the DEEP2 are in dark halos $\sim 4\times10^{11}h^{-1}$ M_{sun} (Zheng+)
- If these central galaxies have the same misalignment distribution as the SDSS LRGs, the II correlation can contribute by 5 – 10% to the shear correlation.

Dependence of II correlation on halo mass (Jing 2002)



Another contamination; Gravitational shear – intrinsic ellipticity correlation

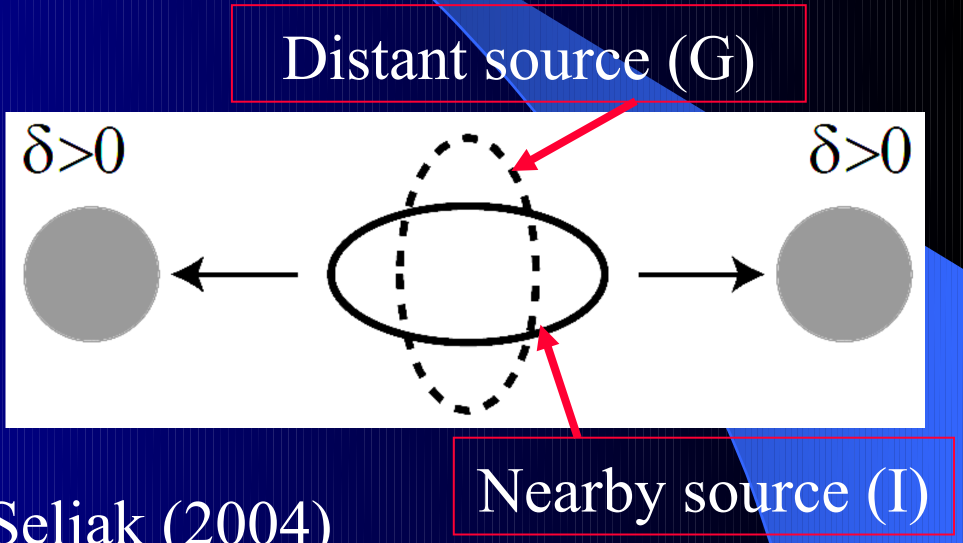
- Observables
  - Ellipticity of galaxies

$$e_{obs} = \gamma + e_s$$

$$\langle e_{obs} e_{obs} \rangle = \underset{\text{GG}}{\langle \gamma\gamma \rangle} + \underset{\text{II}}{\langle e_s e_s \rangle}$$

$$+ \langle \gamma e_s \rangle + \langle e_s \gamma \rangle$$

GI terms Hirata & Seljak (2004)

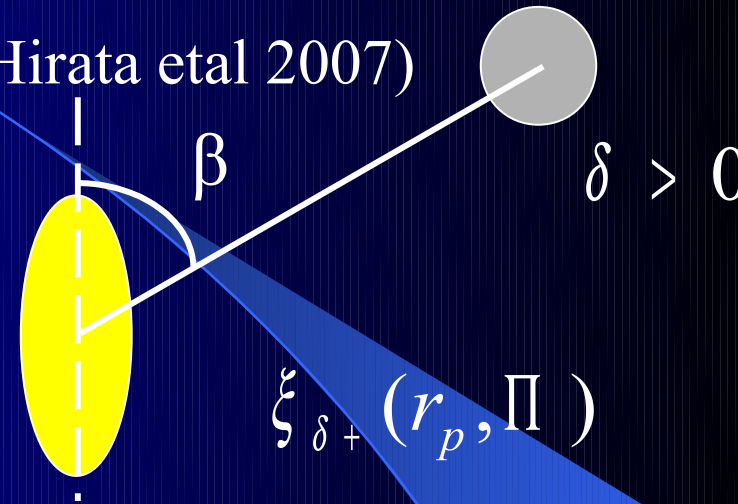


- Unlike II correlation, GI correlation can exist between galaxies at very different redshifts.

Measuring the GI correlations

- Definitions (Mandelbaum etal 2006, Hirata etal 2007)
  - Ellipticity of galaxies

$$e_+ = \frac{1-q^2}{1+q^2}\cos 2\beta = \cos 2\beta$$



  - Projected GI correlation function

$$w_{\delta+}(r_p) = \int \xi_{\delta+}(r_p, \Pi)\, d\Pi$$

$$= w_{g+}(r_p)/\underline{b_g}$$

Galaxy biasing
~2 for LRGs

Directly related to the GI term
of the shear power spectrum.

Clear detection of GI correlation in LRG

- Definitions (Mandelbaum etal 2006, Hirata etal 2007)
  - Ellipticity of galaxies

$$e_+ = \frac{1-q^2}{1+q^2}\cos 2\beta = \cos 2\beta$$

  - Projected GI correlation f

$$w_{\delta+}(r_p) = \int \xi_{\delta+}(r_p,\Pi)\,d$$

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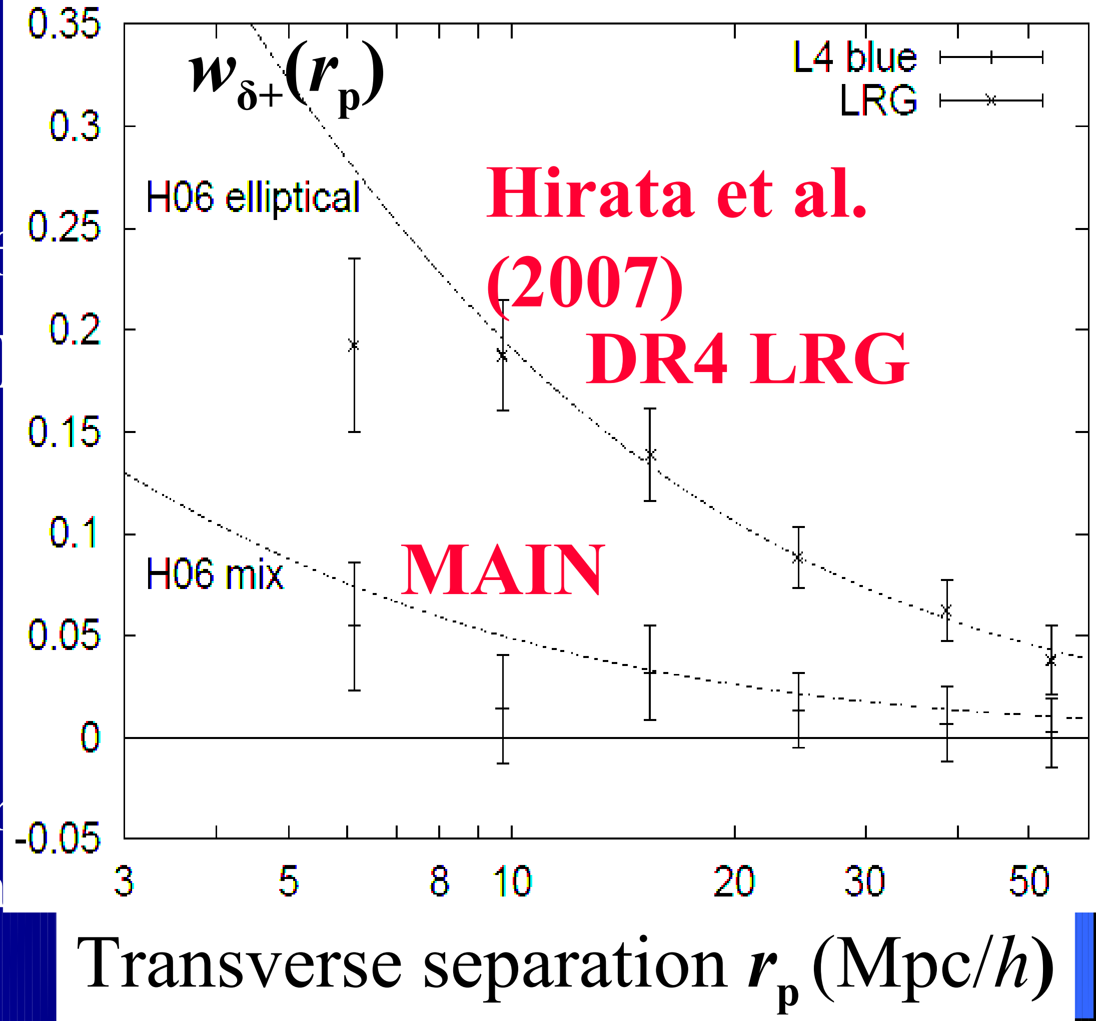
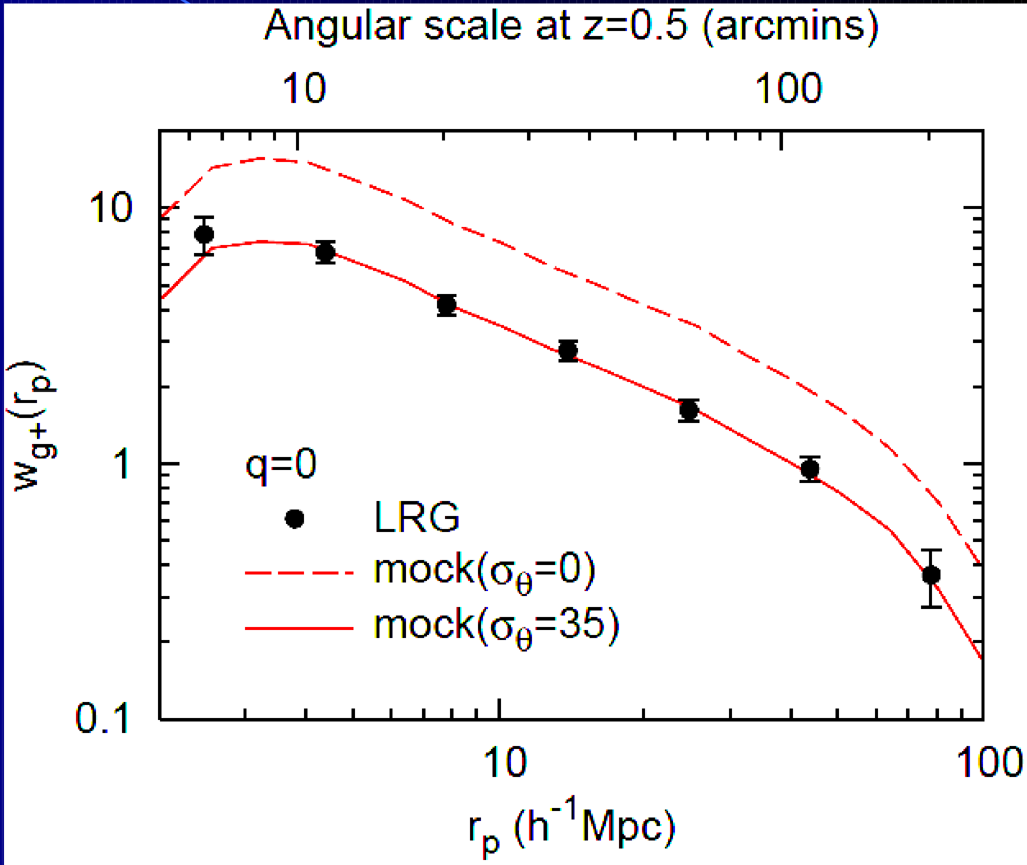


The GI correlation functions of LRGs in observation and in LCDM model

- The GI correlation is better determined than the II correlation in observation.
- The GI correlation can be well modeled in the current LCDM model with the misalignment angle parameter obtained by the II correlation



This method loses no statistical signal!

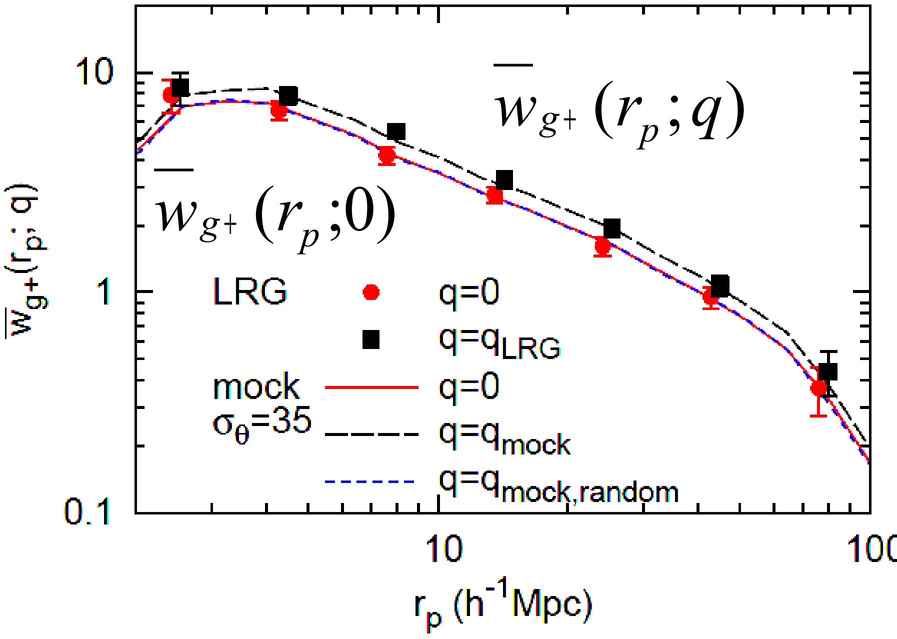
Correlation of the LRG shape and orientation

- Normalized GI correlation function

$$\bar{w}_{g+}(r_p;q) = \left\langle \frac{1-q^2}{1+q^2} \right\rangle^{-1} w_{g+}(r_p;q)$$

$$\propto \left\langle \frac{1-q^2}{1+q^2} \right\rangle^{-1} \frac{1}{N_{\mathrm{pair}}} \sum_i^{N_{\mathrm{pair}}} \frac{1-q_i^2}{1+q_i^2} \cos 2\beta_i$$

axis ratio   orientation



  - If there is no correlation between q and β, we expect

$$\bar{w}_{g+}(r_p;q) = \bar{w}_{g+}(r_p;0)$$

- This correlation increases the amplitude by ~15%.

Flowchart of the work

$$\langle e_{obs} e_{obs} \rangle = \underset{\text{GG}}{\langle \gamma\gamma \rangle} + \underbrace{\langle e_s e_s \rangle}_{\text{II}} + \underbrace{\langle e_s \gamma \rangle + \langle \gamma e_s \rangle}_{\text{GI}}$$

Observation

II correlation $c_{11}(r)$

constraint on σ_θ

$w_{g+}(r_p)$ is modeled!

II correlation $c_{11}(r\,;\sigma_\theta)$

GI correlation $w_{g+}(r_p;\sigma_\theta)$

Mock galaxy catalog

Mock galaxy catalog

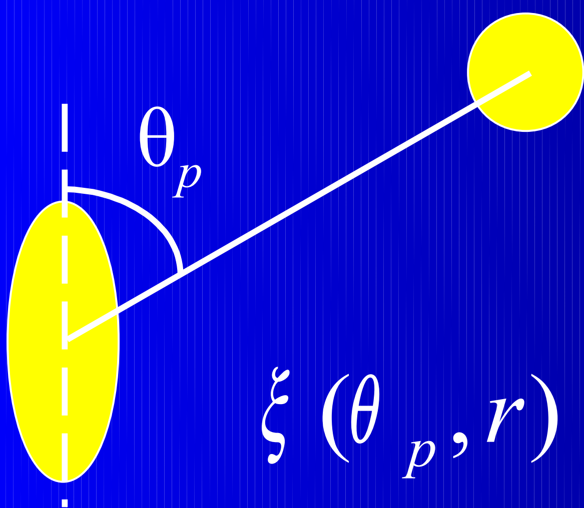
HOD $N(M) + \sigma_\theta$

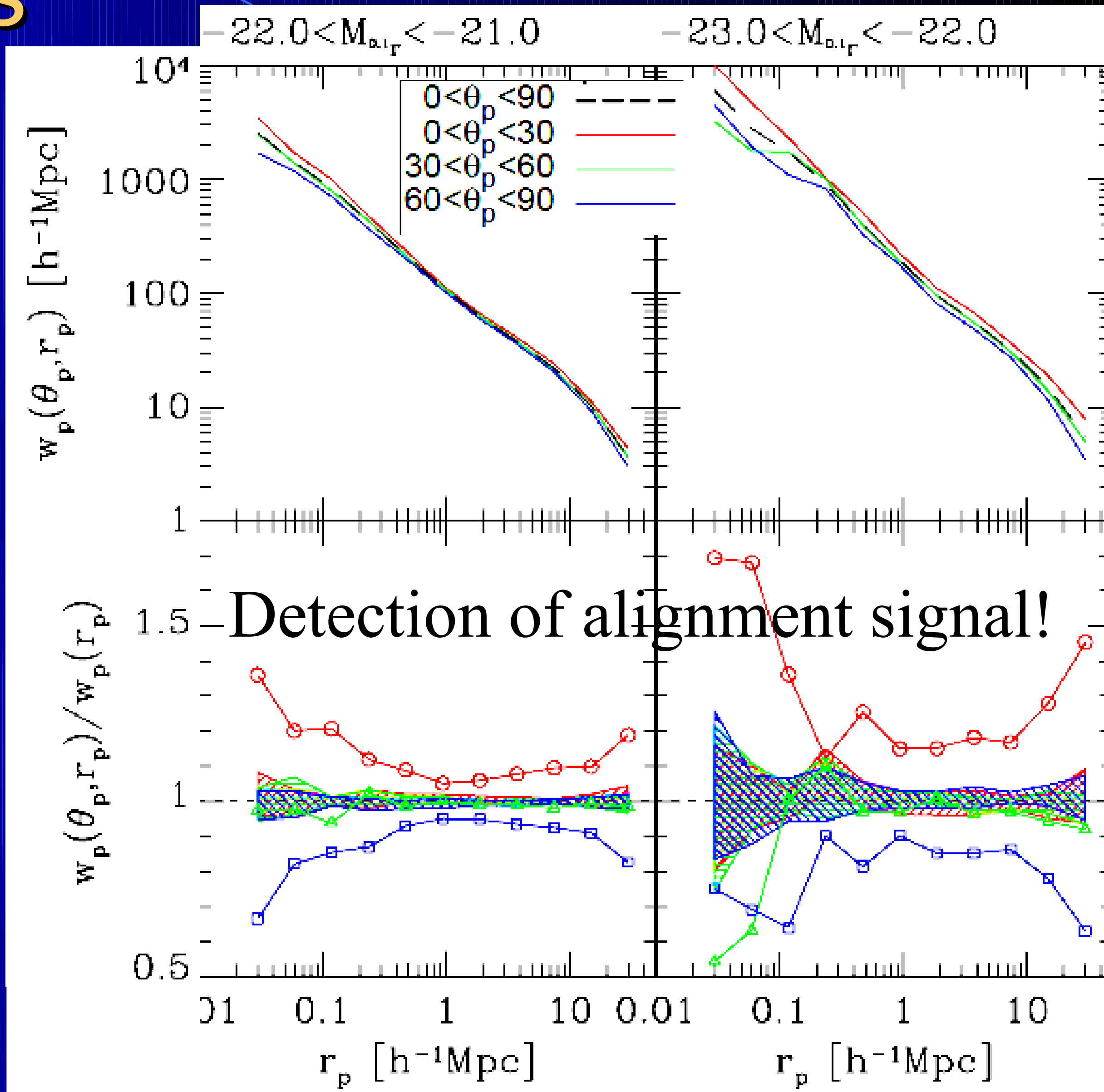
HOD $N(M) + \sigma_\theta$

Theory (simulated ΛCDM halos)

Some preliminary results

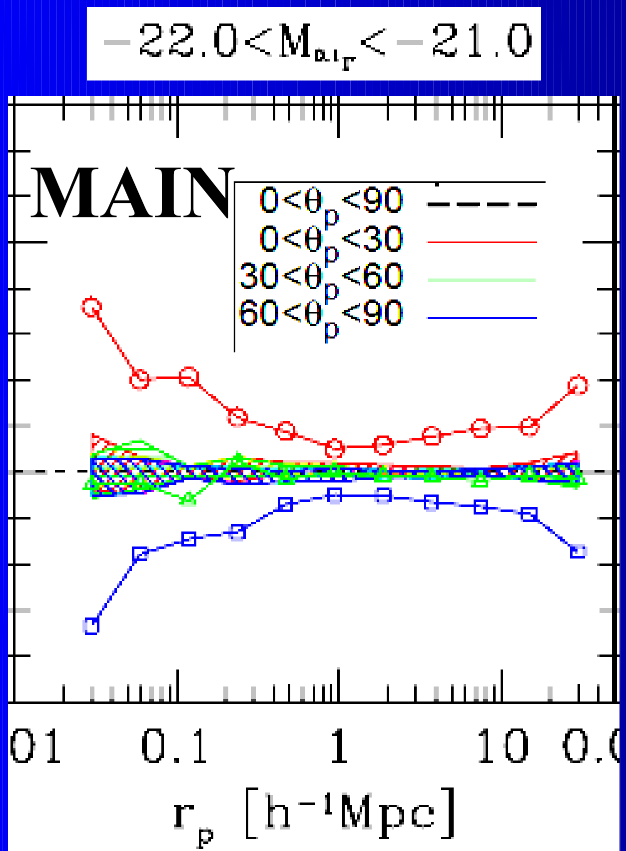
Alignment correlation function of SDSS MAIN galaxies

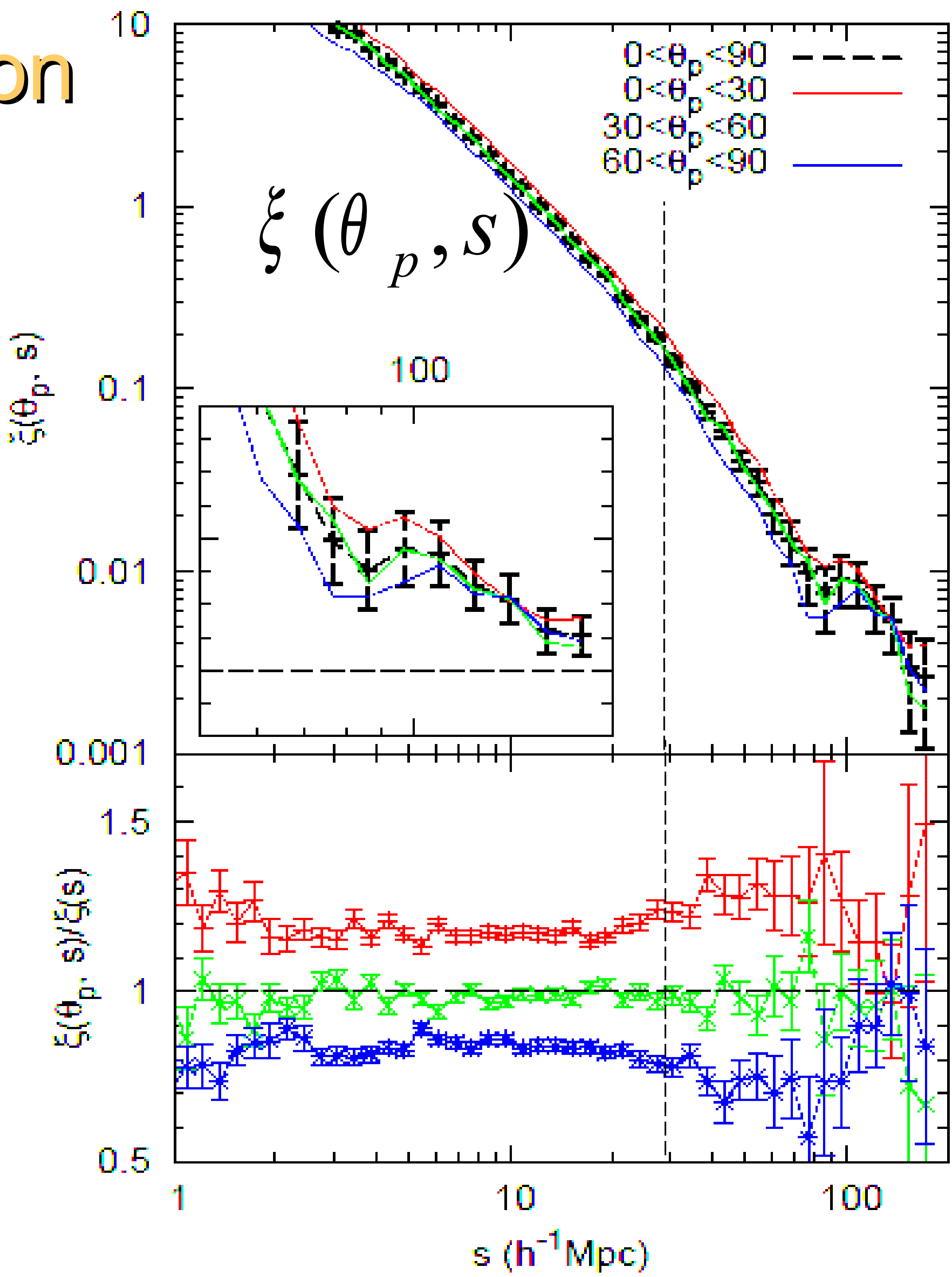




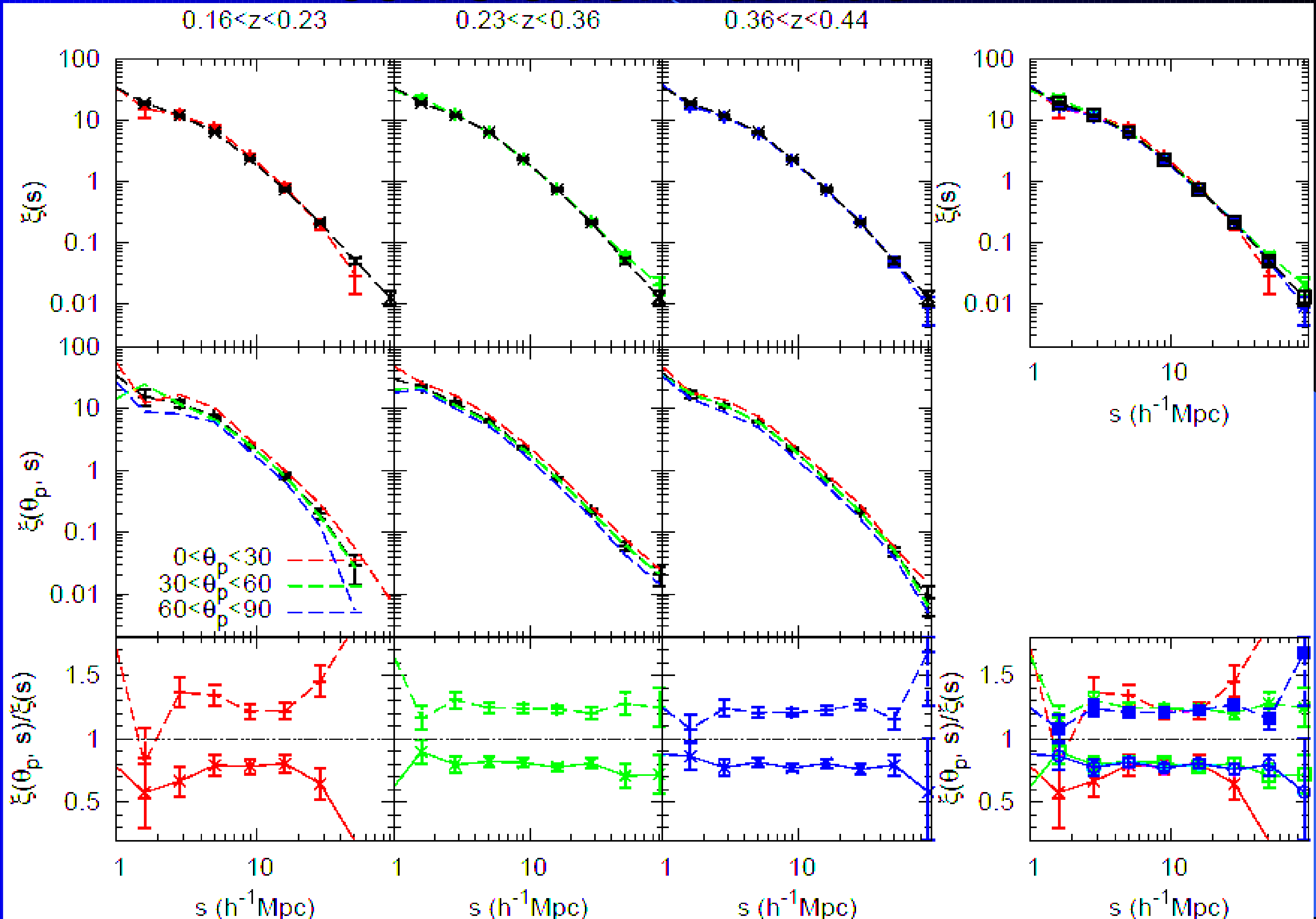
Faltenbacher, Li, White, Jing, et al. (2009)

Alignment correlation function of LRGs from SDSS DR7





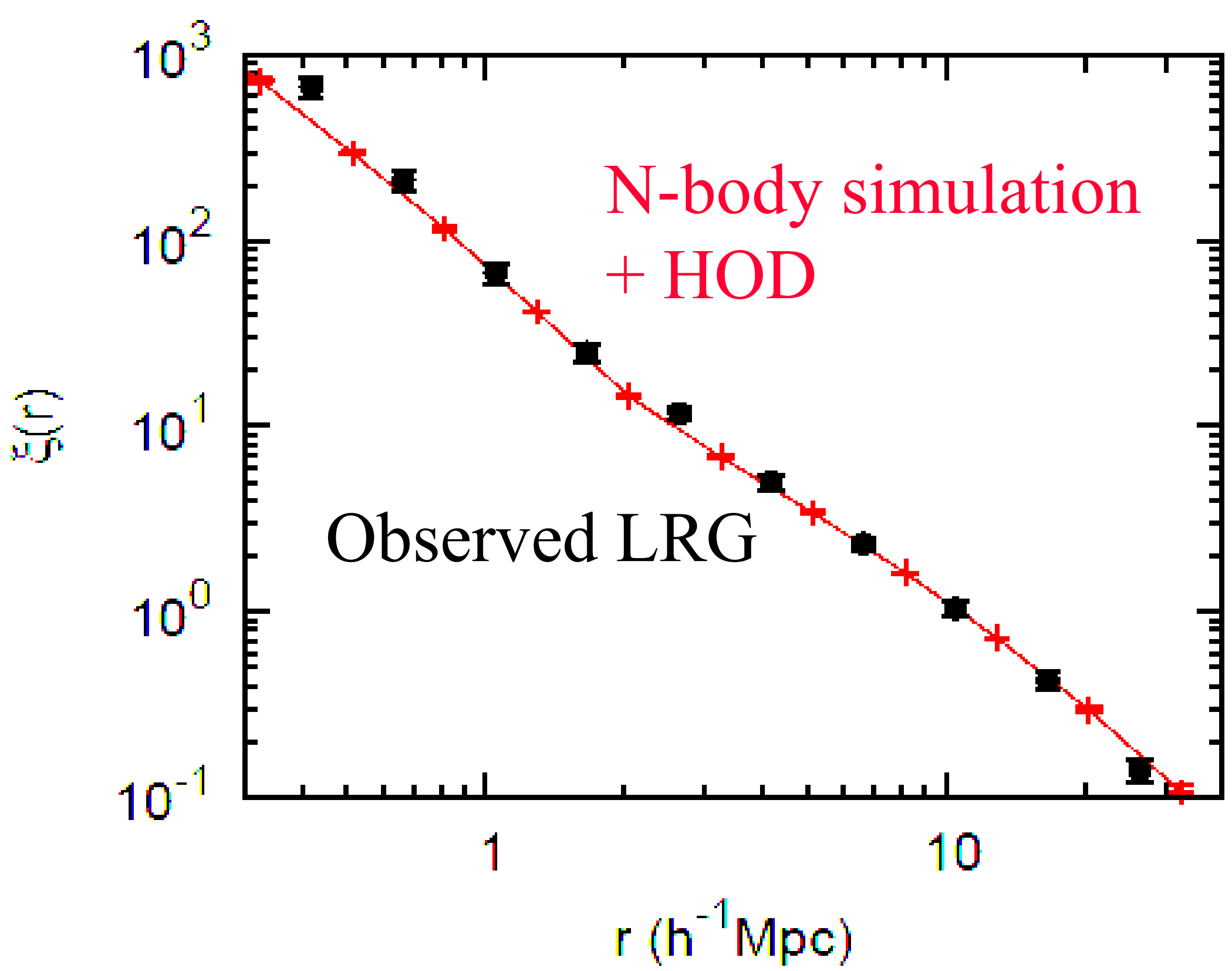
Redshift evolution of alignment correlation function



Conclusion

- The II correlation was accurately determined from the LRG sample from the SDSS DR 6.
- A tight constraint on the misalignment parameter between central LRGs and their host halos, σ_θ=35°, was obtained
- The GI correlation was precisely modeled using σ_θ obtained from the II correlation
- These correlations, if not corrected, can lead to contamination at ~5% level to the shear power spectrum
- Theoretical modeling of alignment correlation function based on N-body simulations will be useful for investigating the relationship between galaxies and large-scale structure.

Comparison between observation and HOD model



GI correlation and alignment correlation functions

- Relationship (Faltenbacher et al. 2009)

$$\boxed{\bar{w}_{g+}(r_p)} = w_p(r_p)\langle\cos(2\theta_p)\rangle(r_p)$$

GI correlation

$$\langle\cos(2\theta_p)\rangle(r_p) = \frac{\int_0^{\pi/2}\cos(2\theta_p)w_p(\theta_p, r_p)d\theta_p}{\int_0^{\pi/2}w_p(\theta_p, r_p)d\theta_p}$$

$$w_p(\theta_p, r_p) = \int_{-\infty}^{\infty}\boxed{\xi(\theta_p, r_p, \Pi)}d\Pi$$

$$w_p(r_p) = w_p(0 \le \theta_p \le \pi/2, r_p)$$

alignment correlation

Faltenbacher et al. (2009)