Three-point correlation functions and bispectra of SDSS galaxies: implications for linear and quadratic biasing coefficients

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Collaborators

- **Issha Kayo**, Suto, Nichol, Pan, Szapudi, Connolly, Gardner, Jain, Kulkarni, Matsubara, Sheth, Szalay, and Brinkmann
  - Three-Point Correlation Functions of SDSS Galaxies in Redshift Space: Morphology, Color, and Luminosity Dependence
  - PASJ 56(2004)415
- **Takahiro Nishimichi**, Kayo, Hikage, Yahata, Taruya, Jing, Sheth and Suto
  - Bispectrum and nonlinear biasing of galaxies: perturbation analysis, numerical simulation and SDSS galaxy clustering
  - PASJ, submitted (2006)

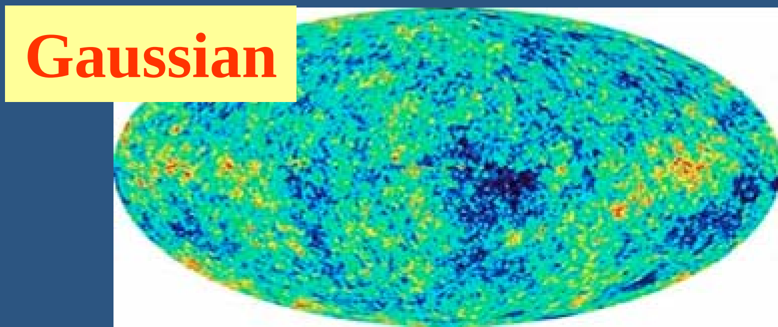
How galaxies trace mass ?

- **galaxy biasing**
  - SDSS significantly advanced our knowledge of galaxy distribution on large scales
  - how to relate it to mass (dark matter) distribution ?
- **empirical perturbation expansion**

$$\delta_{gal} = b_1 \delta_{mass} + \frac{b_2}{2} \delta_{mass}^2 + \cdots$$

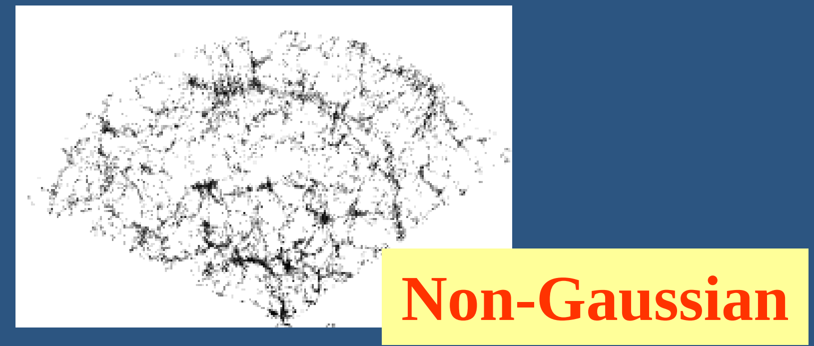
  - often consider the linear term alone (for two-point statistics, or in linear regimes)
  - higher-order terms ? ⇒ higher-order statistics

Three-point correlation function

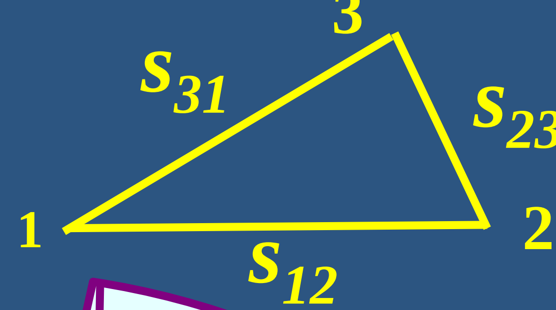


Nonlinear gravity

Nonlinear bias

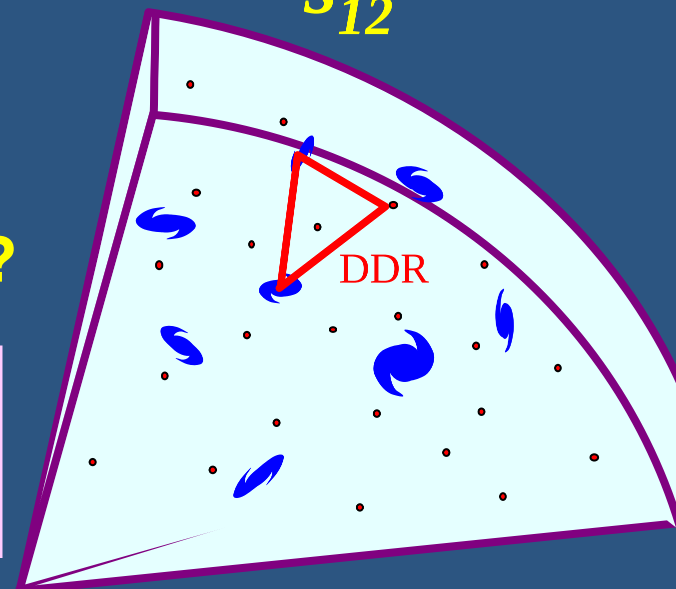


$$dP_{123} = n^3[1 + \xi(s_{12}) + \xi(s_{12}) + \xi(s_{12}) + \zeta(s_{12}, s_{23}, s_{31})]\, dV_1 dV_2 dV_3$$

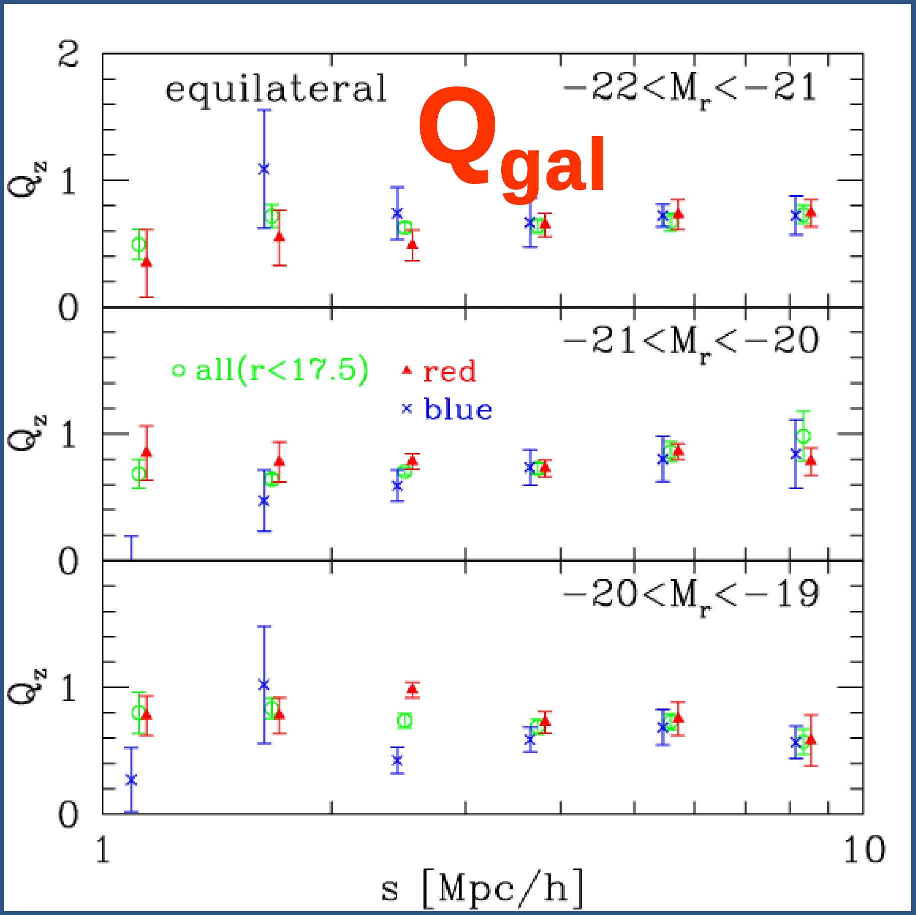


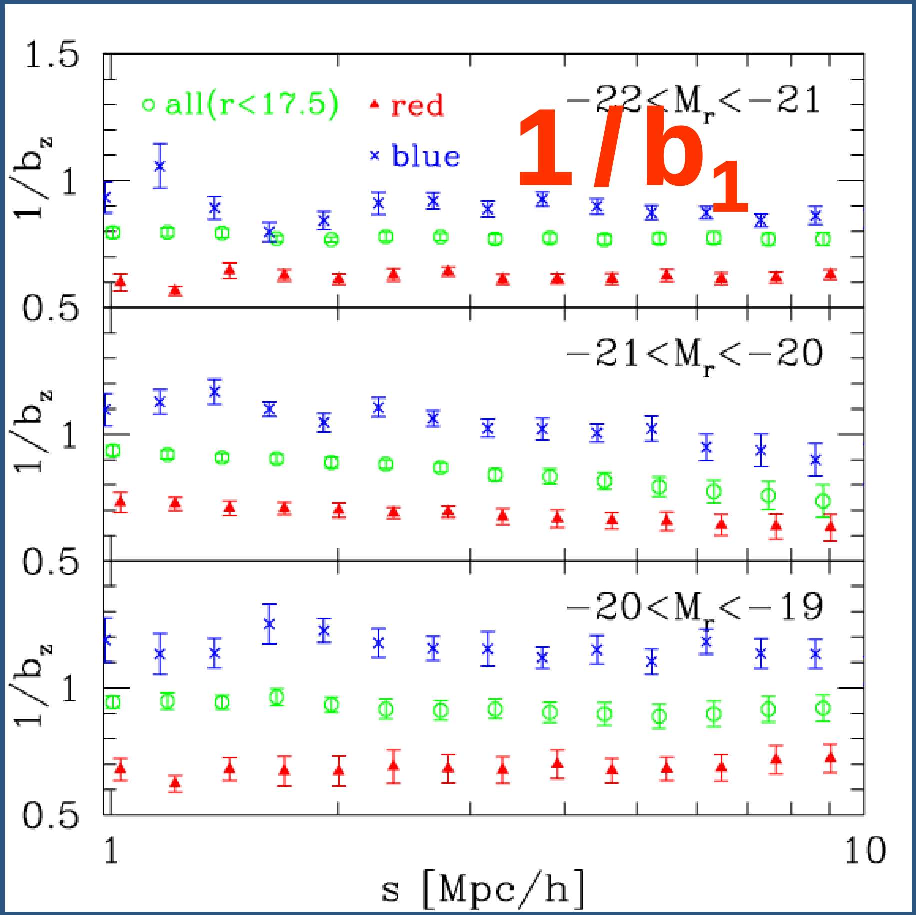
- vanishes for Gaussian field
- The simplest statistics to probe the non-Gaussianity (phase information)
- **how galaxies trace mass (biasing) ?**

$$Q \equiv \frac{\zeta(s_1, s_2, s_3)}{\xi(s_1)\xi(s_2) + \xi(s_2)\xi(s_3) + \xi(s_3)\xi(s_1)}$$



3pt correlation functions of SDSS galaxies *in redshift space*





Clear luminosity, morphology and color dependences of (2pt) bias disappear in 3pt amplitude

Kayo et al. PASJ 56(2004) 415

nonlinearity of galaxy bias required

- if linear bias:

$$\delta_{gal} = b_1 \delta_{mass} \Rightarrow \quad Q_{gal} = \frac{Q_{mass}}{b_1}$$

this is clearly inconsistent with SDSS data !

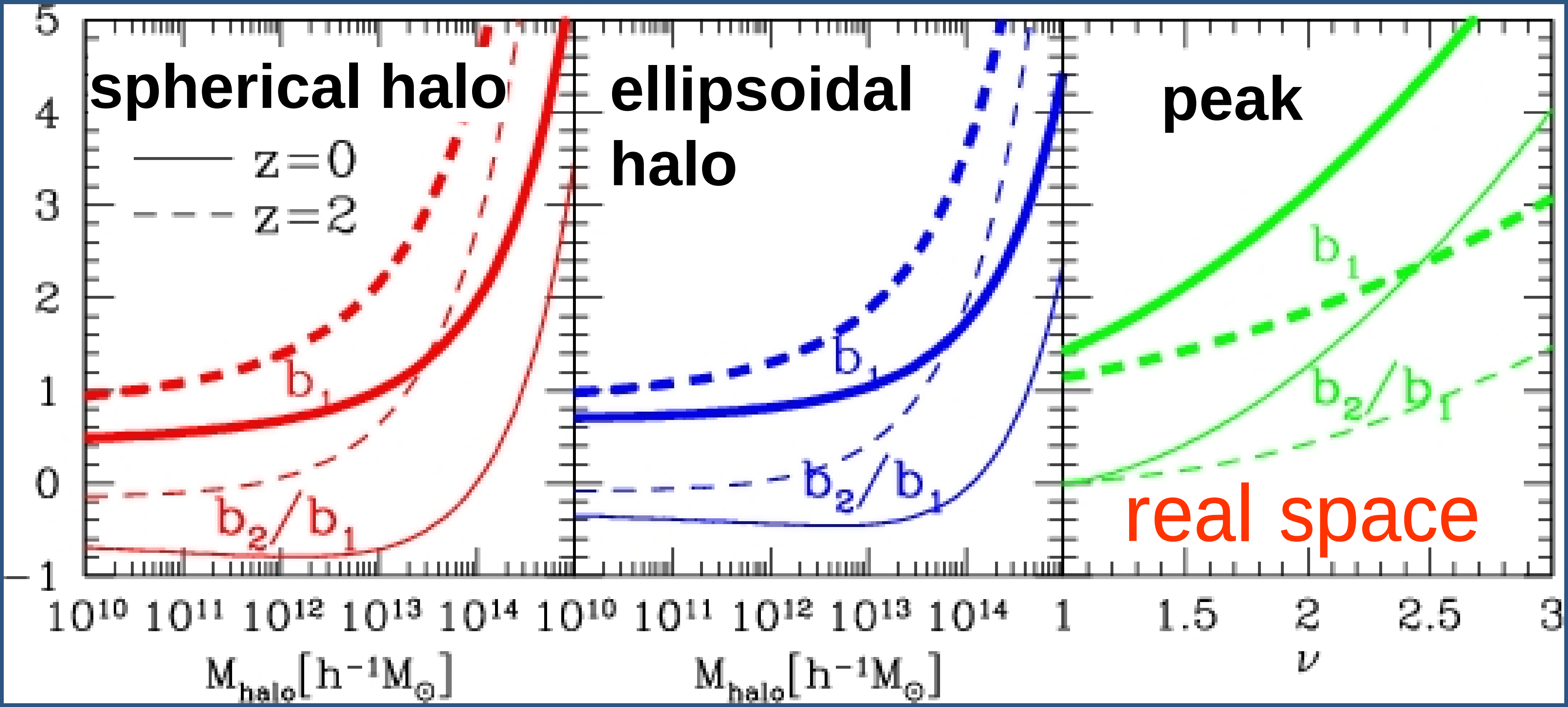
- even in nonlinear bias:

$$\delta_{gal} = b_1 \delta_{mass} + \frac{b_2}{2} \delta_{mass}^2 + \cdots \Rightarrow \quad Q_{gal} = \frac{1}{b_1}\left[Q_{mass} + \frac{b_2}{b_1} \right]$$

still, dependence on b_1 is expected

- **Q=Q(~~b_1~~) ⇒ correlation between b_1 & b_2**

b_2-$b_1$correlation: perturbation model



Nishimichi et al. (2006), submitted to PASJ

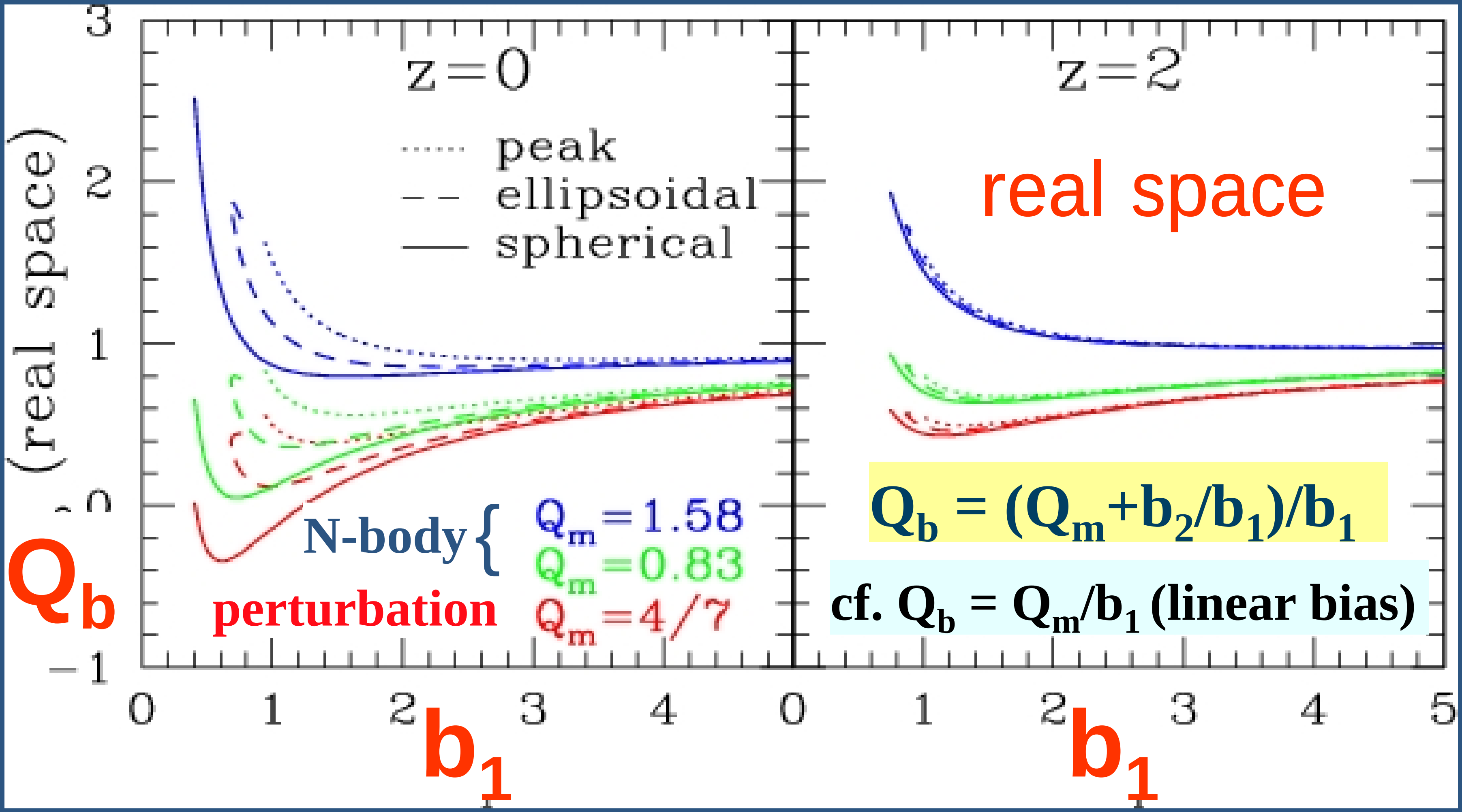
Mo & White(1996)

Mo, Jing & White(1997)

Sheth & Tormen(1999)

Cooray & Sheth(2002)

Q_{halo} and Q_{peak} : perturbation model



Nishimichi et al. (2006)

- Q_b is insensitive to b_1

SDSS galaxies and simulated halos

SDSS color-selected	$g - r < 0.86$ (blue) $g - r > 0.86$ (red)	NYU-VAGC (based on DR4)
SDSS luminosity threshold	$M_{r\ max} = 18.0, 18.5, \ldots, 21.5$, and 22.0 (9 samples)	
Mass-selected halos	$< 1.2 \times 10^{13}\ h^{-1}M_{sun}$ (S) $> 1.2 \times 10^{13}\ h^{-1}M_{sun}$ (L) $> 6.7 \times 10^{13}\ h^{-1}M_{sun}$ (LL)	$N=512^3$ N-body sim. (Jing & Suto 1998, 2002) + FOF halo finder + HOD code (Skibba et al. 2006)
HOD mock galaxies	Parameters adjusted to reproduce observed w(r) (Zehavi et al. 2005)	

Power spectrum and bispectrum

- linear bias:

$$b_1(k) \equiv \sqrt{\frac{P_{gal}(k)}{P_{mass}(k)}}$$

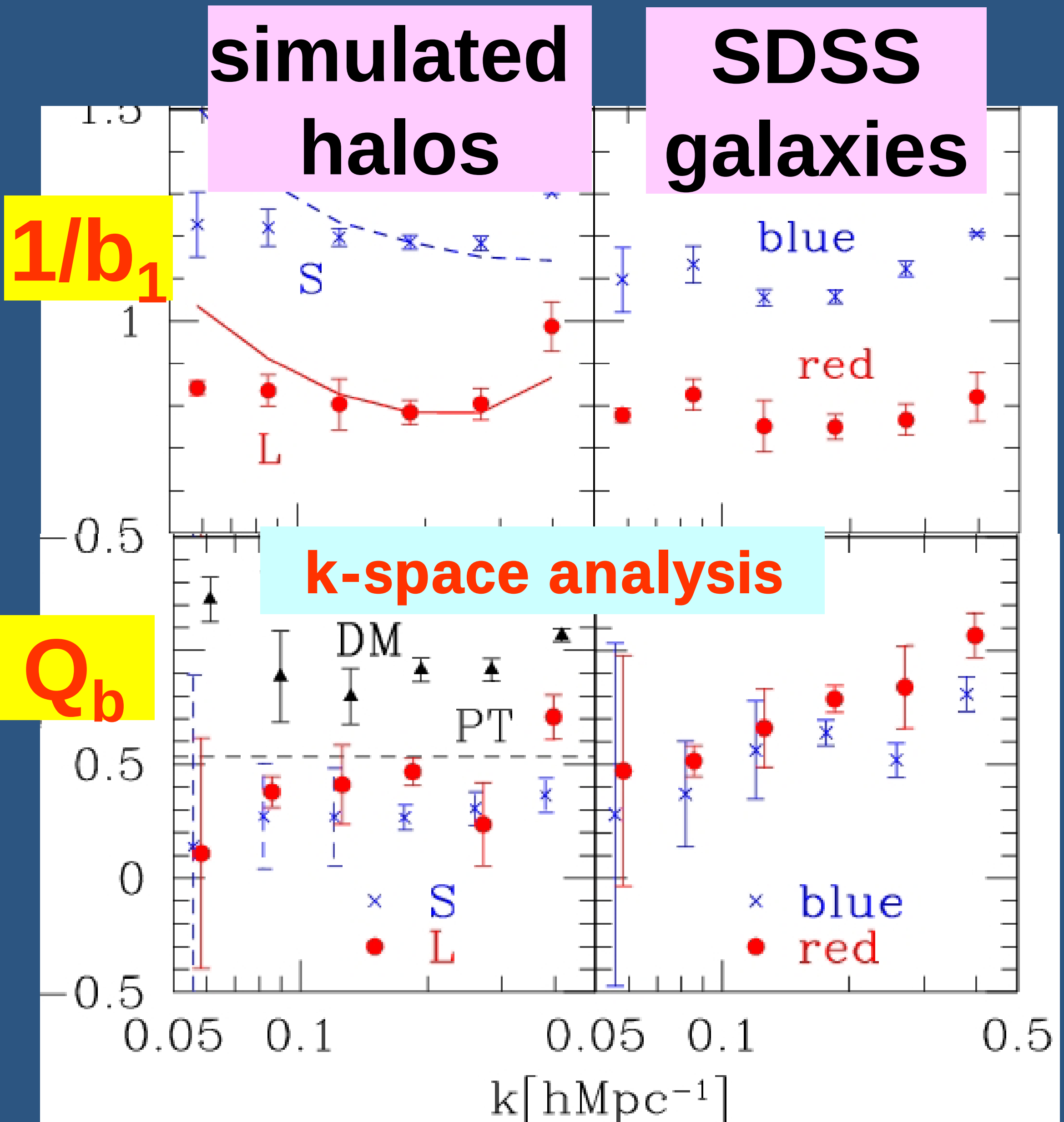
- Q for equilateral triangles ($k_1 = k_2 = k_3$):

$$Q_{gal} \equiv \frac{B_{gal}(k_1, k_2, k_3)}{P_{gal}(k_1)P_{gal}(k_2) + P_{gal}(k_2)P_{gal}(k_3) + P_{gal}(k_3)P_{gal}(k_1)}$$

- quadratic bias:

$$Q_{gal} = \frac{1}{b_1}\left[Q_{mass} + \frac{b_2}{b_1}\right]$$

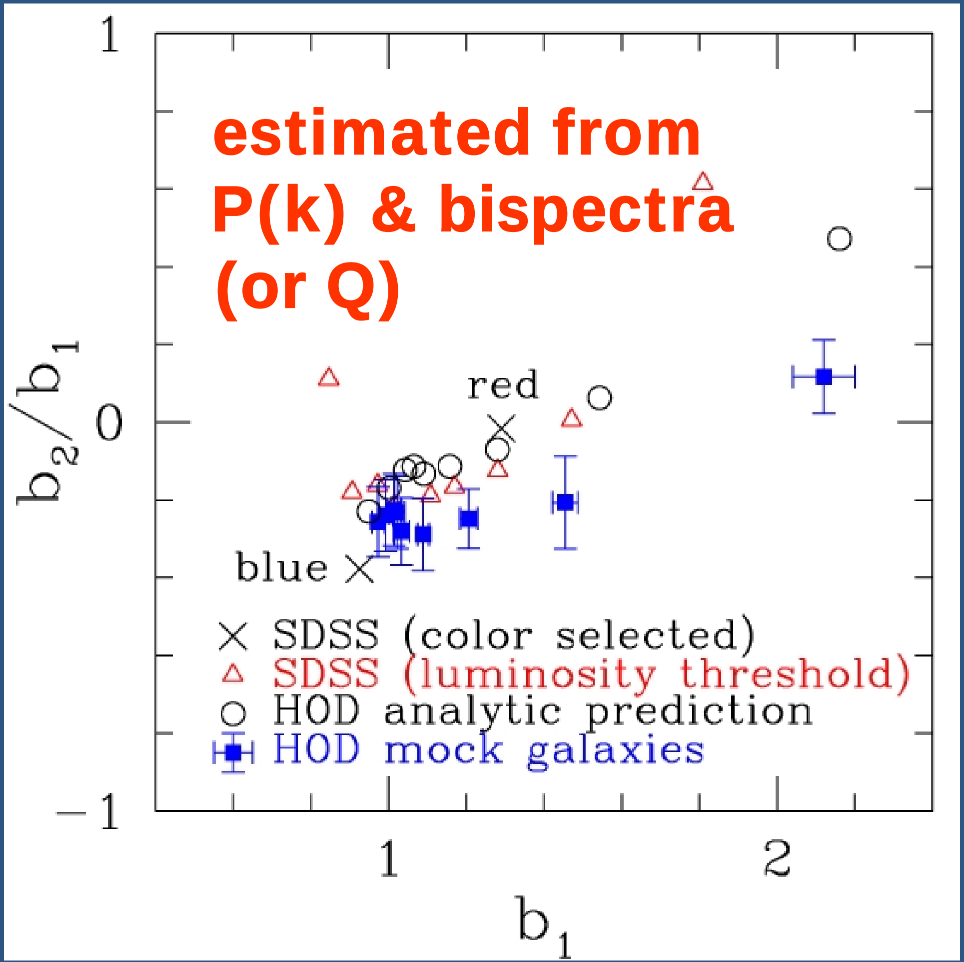
simulated halos vs. SDSS galaxies



- Difference in b_1 does not show up at all in Q_b (b=gal, halo)
- simulated halos reasonably reproduce the behavior of SDSS galaxies

Nishimichi et al.(2006)

b_2/b_1 against b_1 for SDSS galaxies and halo-occupation-distribution model



- ***both SDSS galaxies and HOD models*** **suggest**
  - **a clear trend of b_2/b_1 vs. b_1**
  - **fairly insensitive to bias models**

Nishimichi et al. (2006)

Summary and Conclusions

- insensitivity of Q to b_1 in linear regime
  - confirmed in k-space for SDSS galaxies
  - qualitatively explained in analytic models
  - nonzero b_2 ($\neq$ linear bias model) is the key
  - a generic correlation between b_1 and b_2/b_1
  - redshift-space distortion is a secondary effect
- Beyond the linear bias model
  - nonlinearity in biasing revealed
  - toward better understanding of mass distribution ?
  - goal: b_n as an explicit function of b_1 ?