on detecting assembly bias with galaxy populations

Yen-Ting Lin
Institute of Astronomy & Astrophysics
Academia Sinica

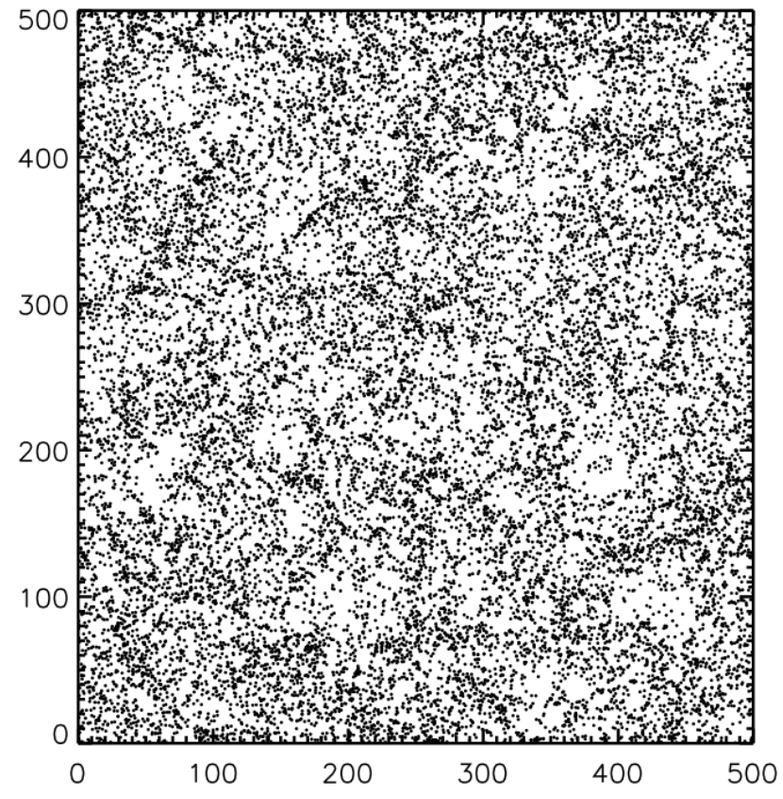
Rachel Mandelbaum, Yun-Hsin Huang, Hung-Jin Huang, Neal Dalal,
Benedikt Diemer, Hung-Yu Jian, Andrey Kravtsov

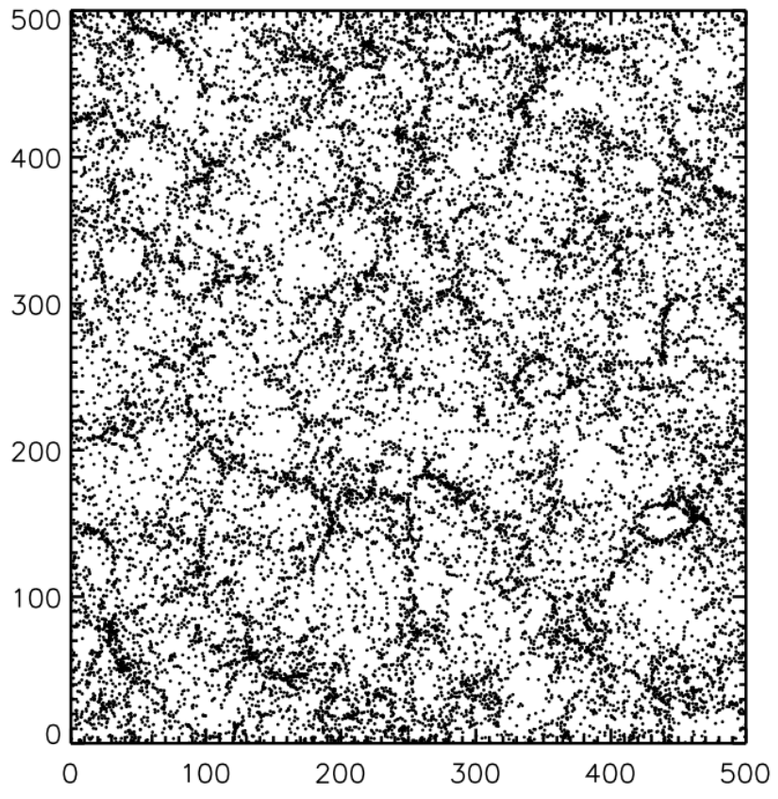
ApJ, submitted (arXiv:1504.07632)

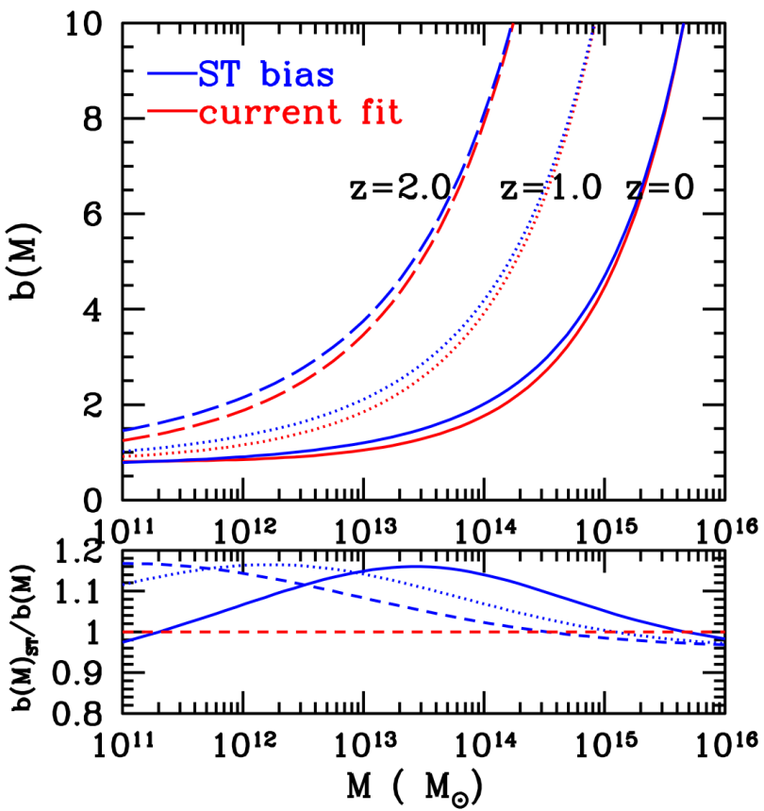
assembly bias

- large scale bias of dark matter halos is primarily a function of halo mass
- a secondary effect is *assembly bias* (**ab**): bias also depends on the halo formation time (Gao+05)
- for low mass halos (~10^{12} $h^{-1}M_{sun}$), those that form earlier would cluster more strongly

Gao+05, Bhattacharya+11

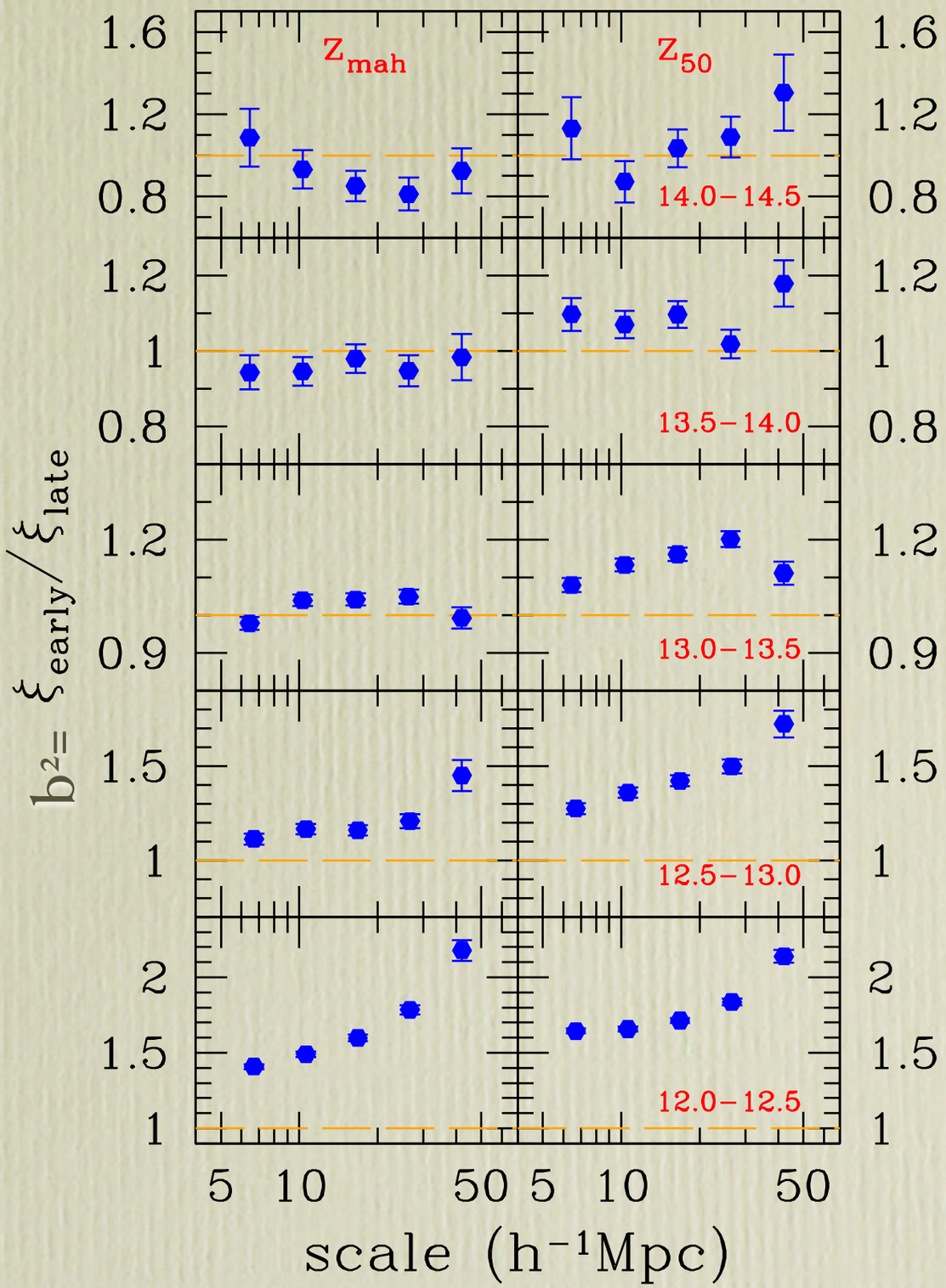






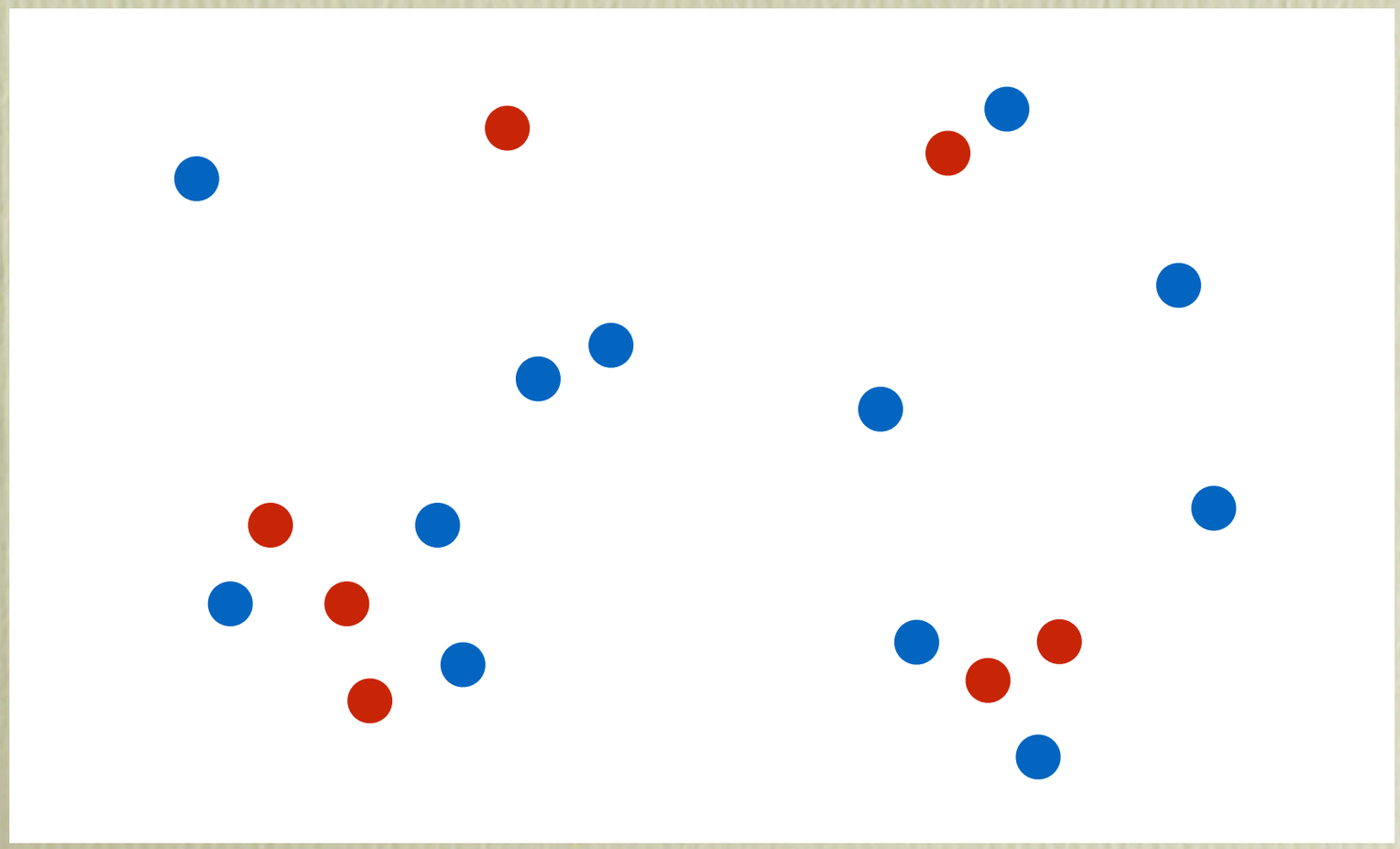
how big is it?

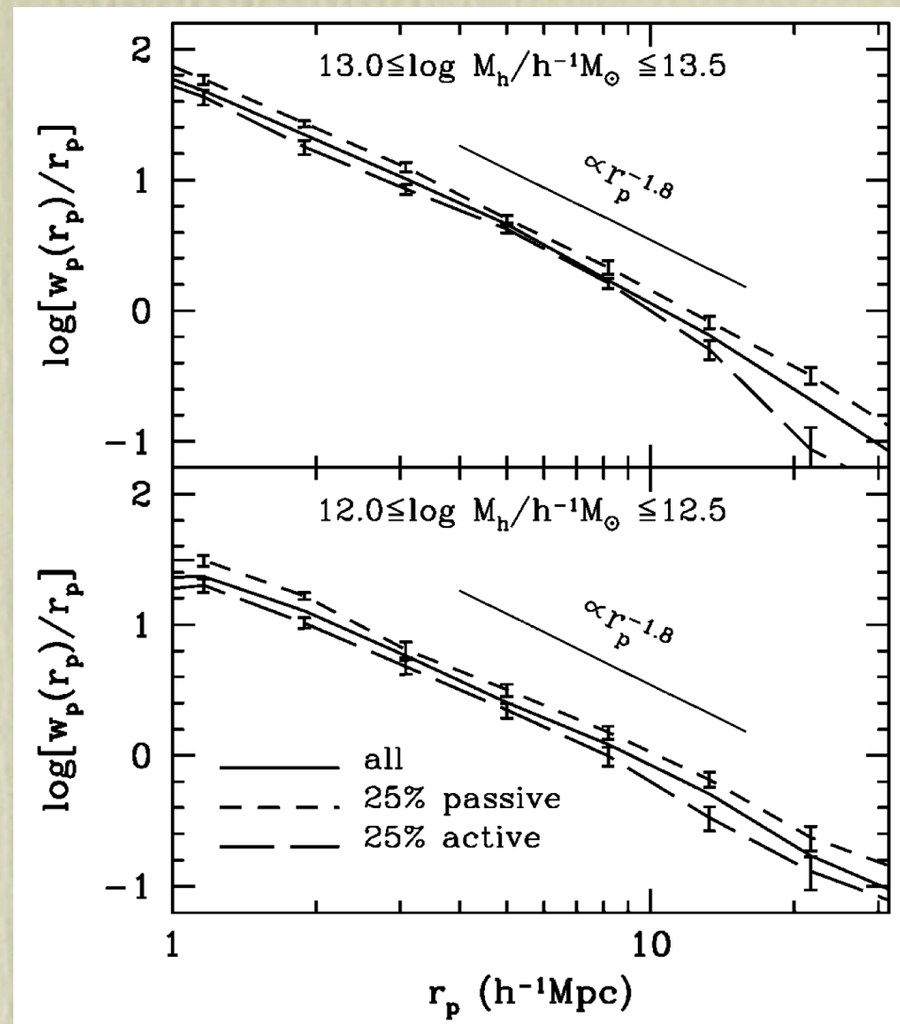
- amplitude of **ab** depends on both halo mass and formation time definition!
- use simulations of Diemer & Kravtsov (2014)
- z_{mah}: $M(z) \propto \exp(-\alpha z)$, $z_{mah}=2/\alpha-1$ (Wechsler+06)
- z_{50}: redshift when a halo has acquired 50% of its final mass
- with z_{mah}, see sign change at high mass end: younger halos are more strongly clustered
- not the case with z_{50}

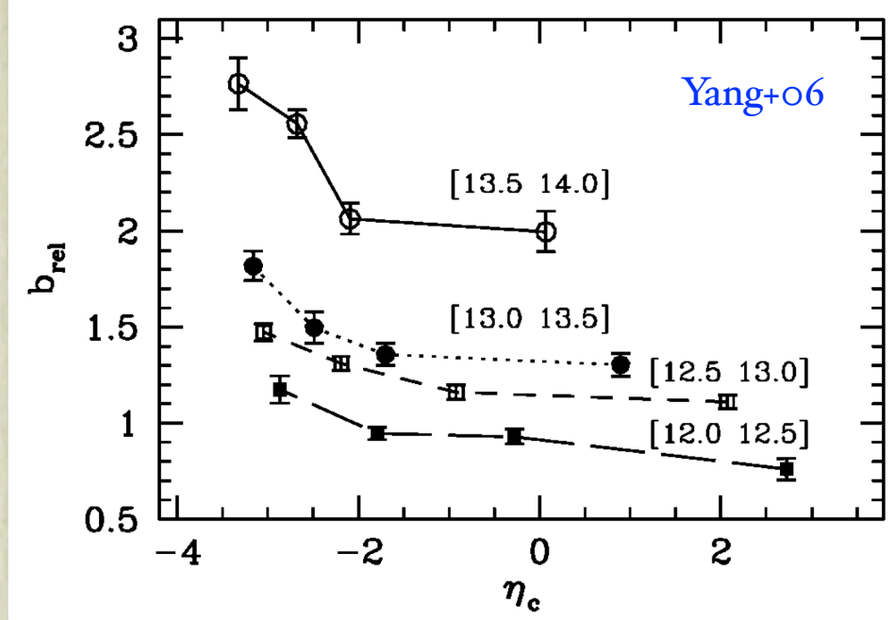


wasn't this detected long ago?

- Yang+06 first claimed detection
  - a catalog that classifies galaxies into single and multiple galactic systems
  - designation of central vs satellite galaxies
  - halo mass *assigned* to each system à la abundance matching technique

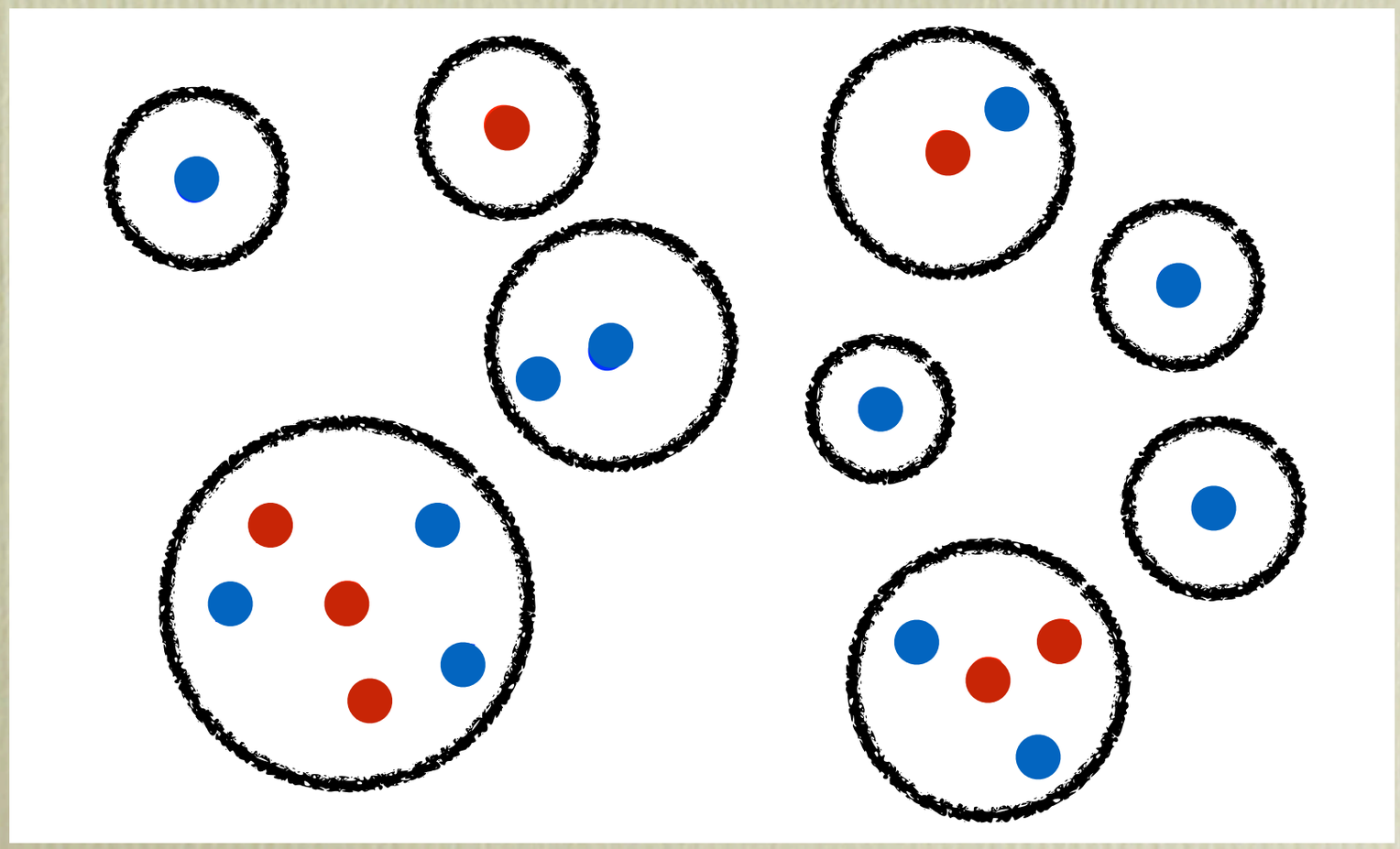


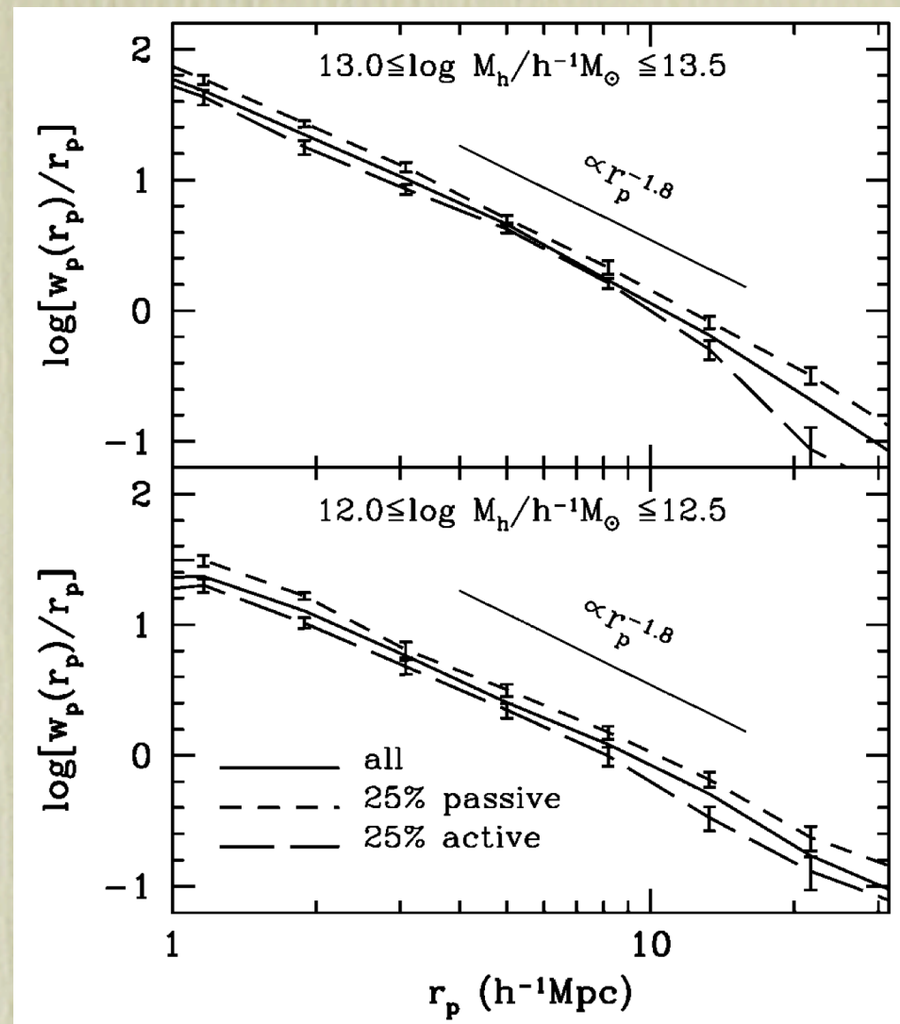


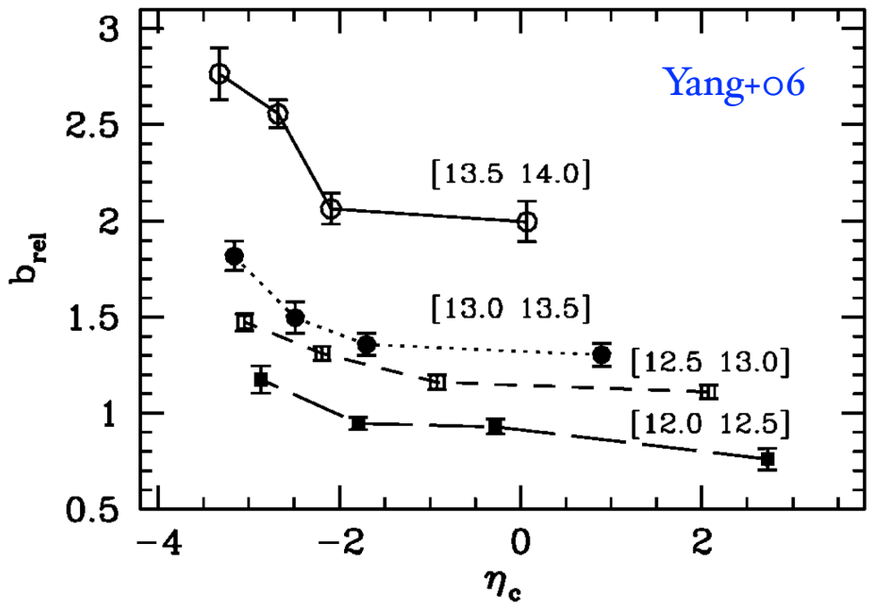


wasn't this detected long ago?

- Yang+06 first claimed detection
  - a catalog that classifies galaxies into single and multiple galactic systems
  - designation of central vs satellite galaxies
  - halo mass *assigned* to each system à la abundance matching technique

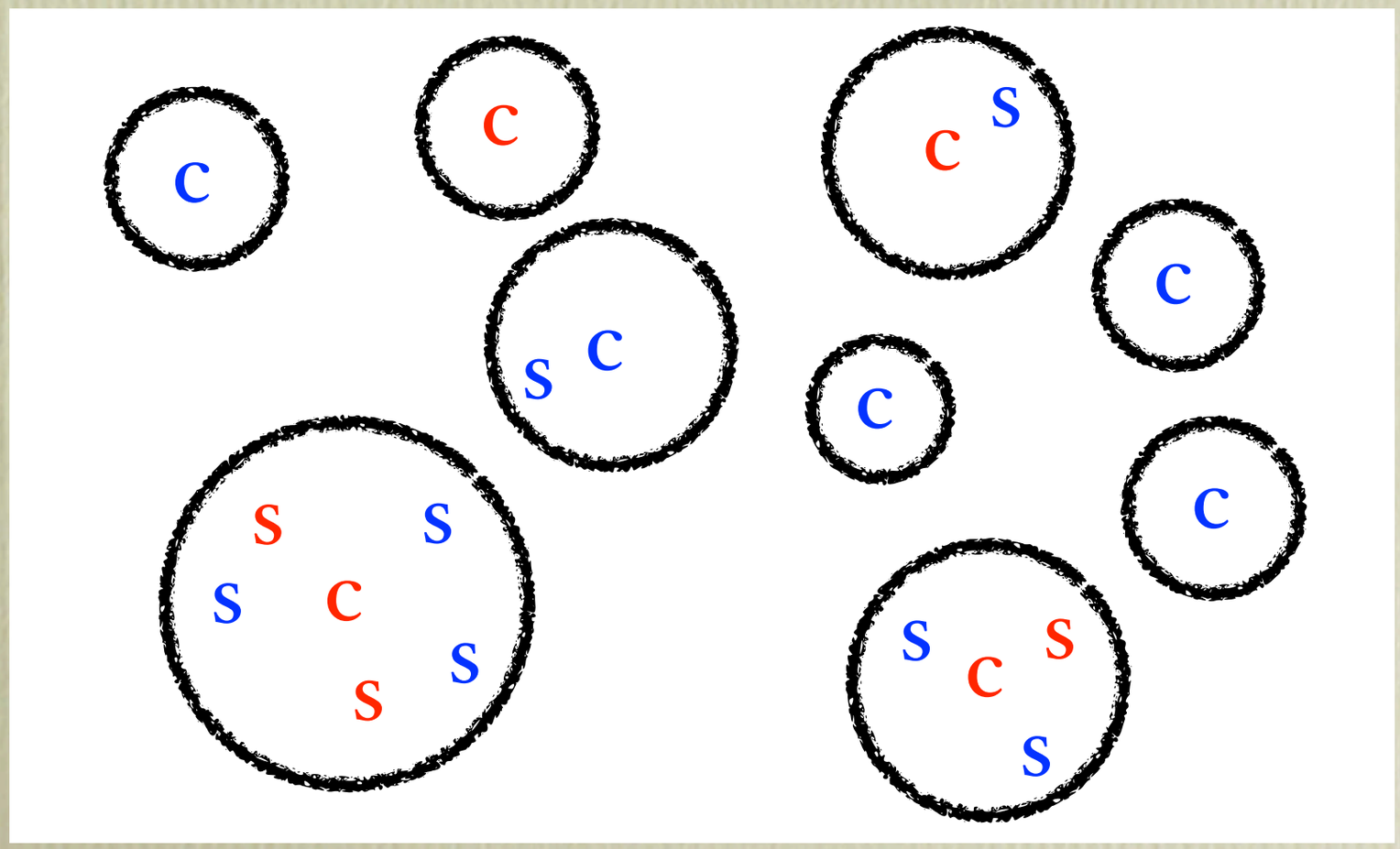


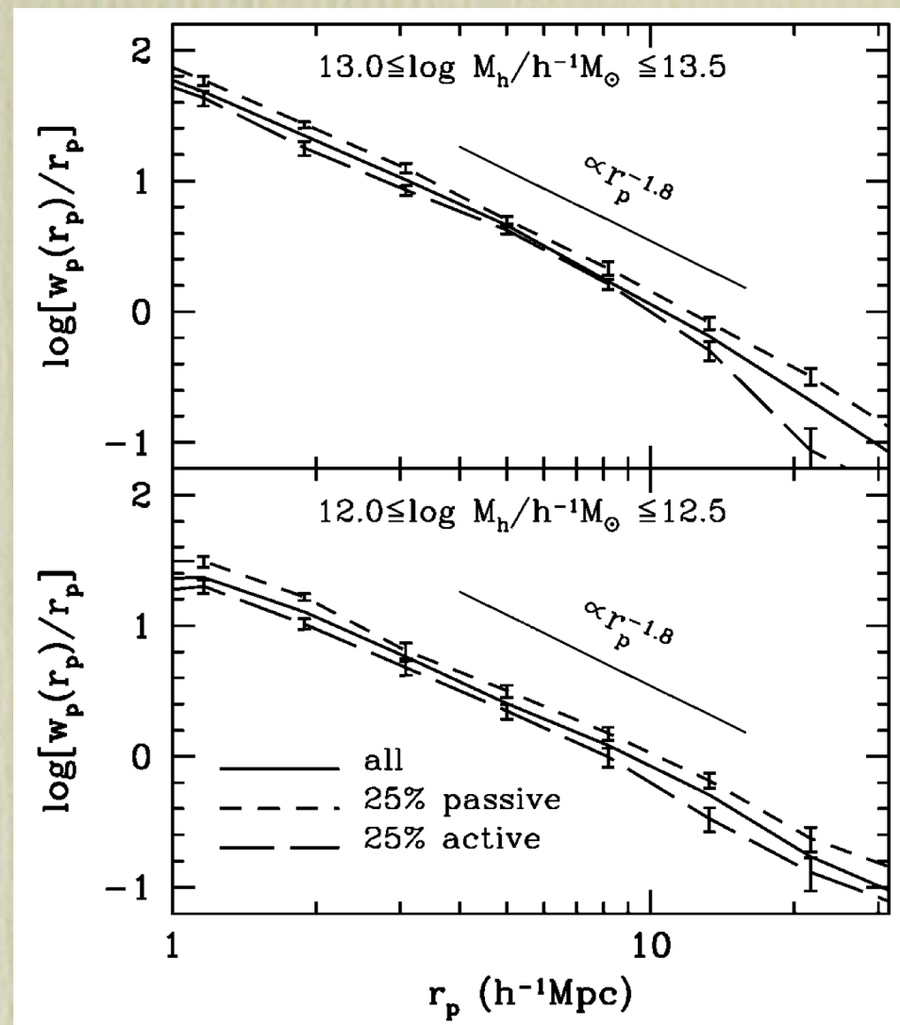


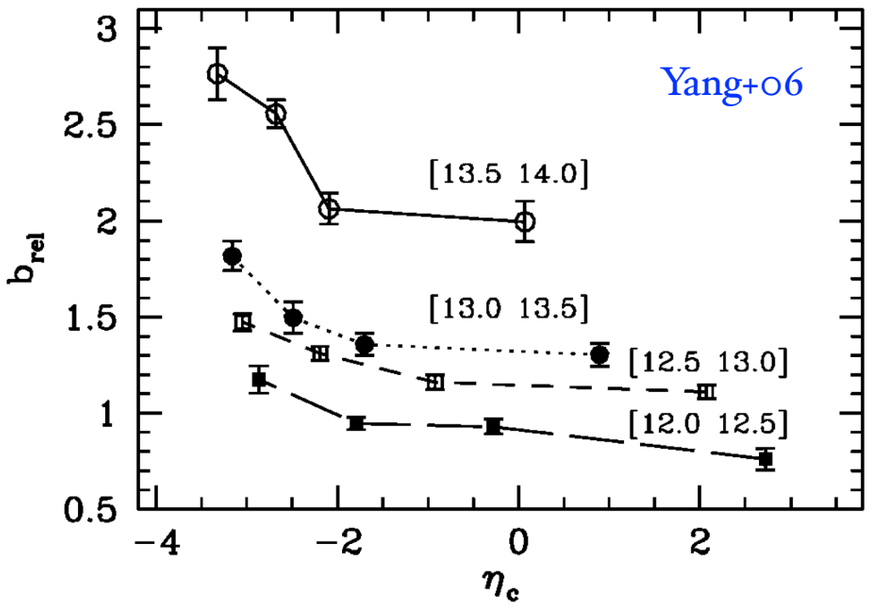


wasn't this detected long ago?

- Yang+06 first claimed detection
  - a catalog that classifies galaxies into single and multiple galactic systems
  - designation of central vs satellite galaxies
  - halo mass *assigned* to each system à la abundance matching technique

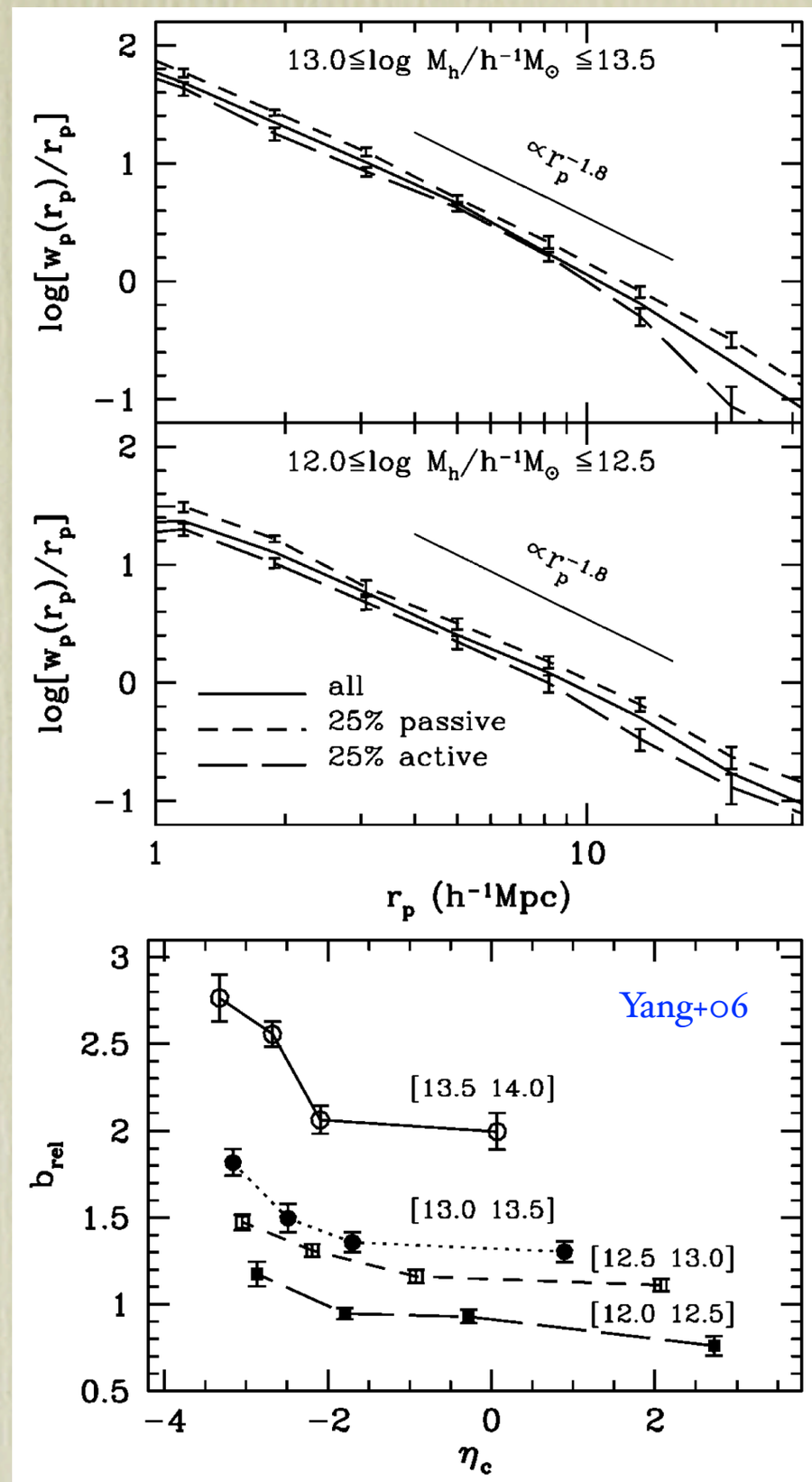






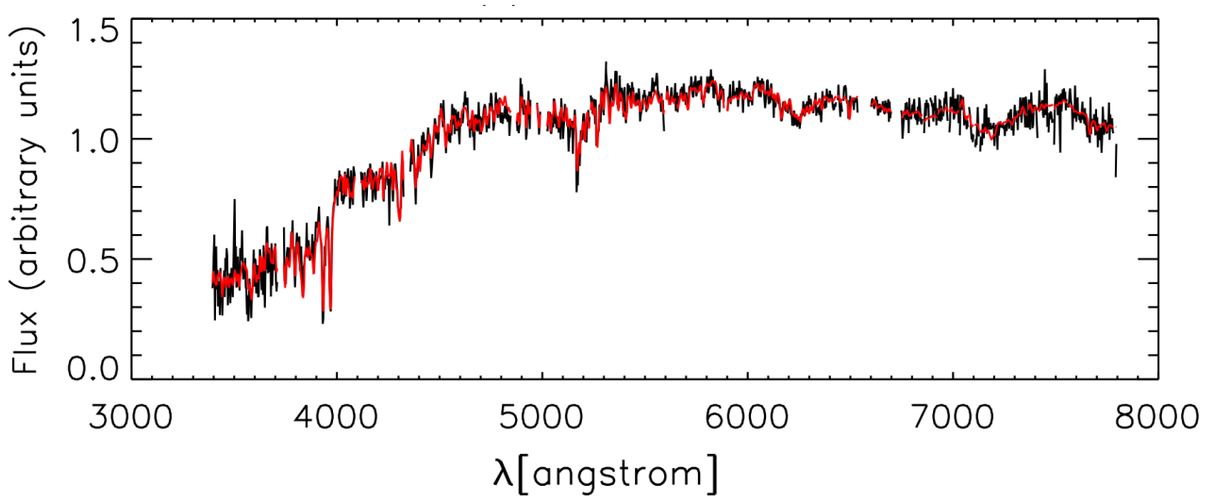
wasn't this detected long ago?

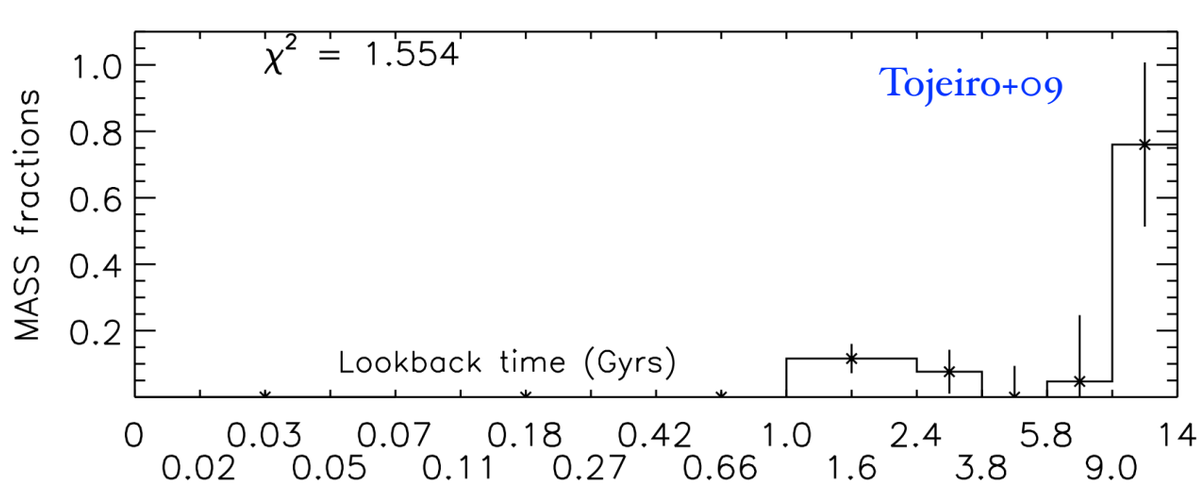
- Yang+06 first claimed detection
  - a catalog that classifies galaxies into single and multiple galactic systems
  - designation of central vs satellite galaxies
  - halo mass *assigned* to each system à la abundance matching technique
- formation history of central galaxies *assumed* to be closely related to that of the halos
- Yang+06 found that halos with currently passive centrals have larger bias than those with star-forming centrals of the *same* halo mass
  - if passive ↔ old, star-forming ↔ young, then this indicated assembly bias



motivation

- checking/improving upon Yang+06 results
  - abundance matching-based mass M_{Yang} vs weak lensing mass
  - using sSFR instead of η (≈SFR)
- using temporarily resolved star formation history from *VESPA* (Tojeiro+09) to distinguish old halos from young ones
  - assuming the star formation history (SFH) of central galaxies correlates with the formation history of host halos

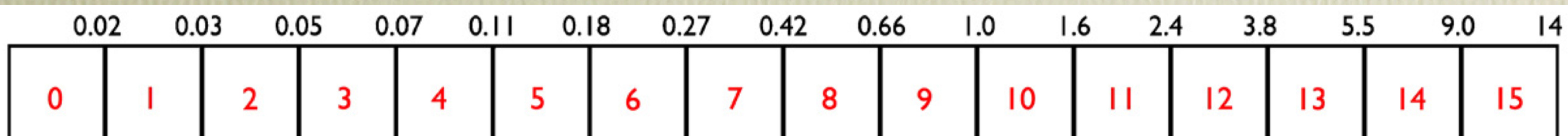




sample

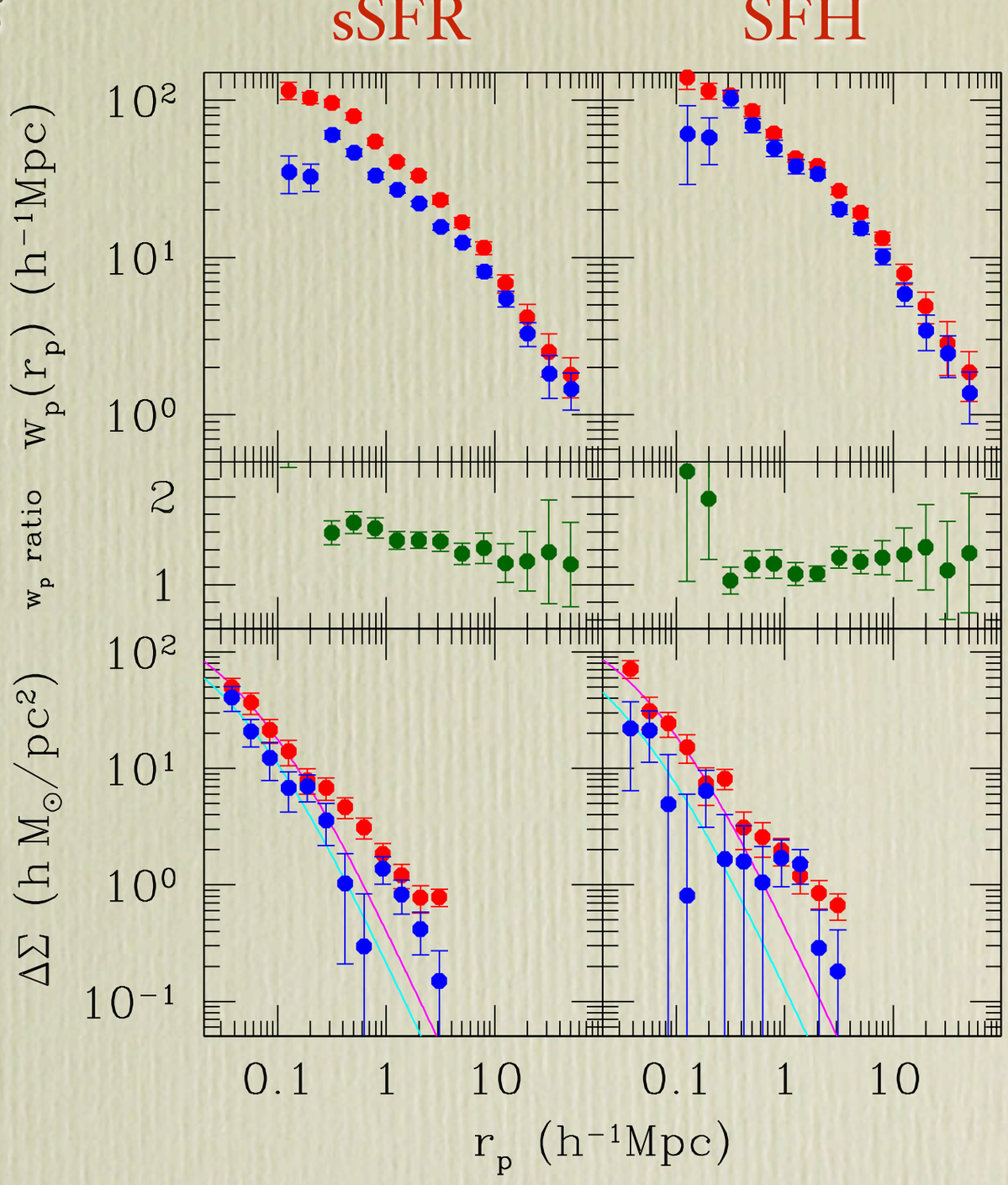
- SDSS DR7 version of Yang's group catalog
  - central galaxies chosen by proximity to geometrical center
  - halo mass via luminosity content ranking
  - SFH from *VESPA*
    - early-forming galaxy: having 50% of its M_{star} formed in first temporal bin (9 Gyr ago; $z>1.9$ if $z_{obs}=0.1$)
    - late-forming: 50% of M_{star} formed after first bin
  - sSFR from MPA/JHU value added galaxy catalog
- galaxy-galaxy lensing measurement
  - shear catalog from Reyes+12
  - lensing mass obtained by fitting NFW profile to observed $\Delta\Sigma$ (over 0.04-1 h^{-1}Mpc)

Tojeiro+09

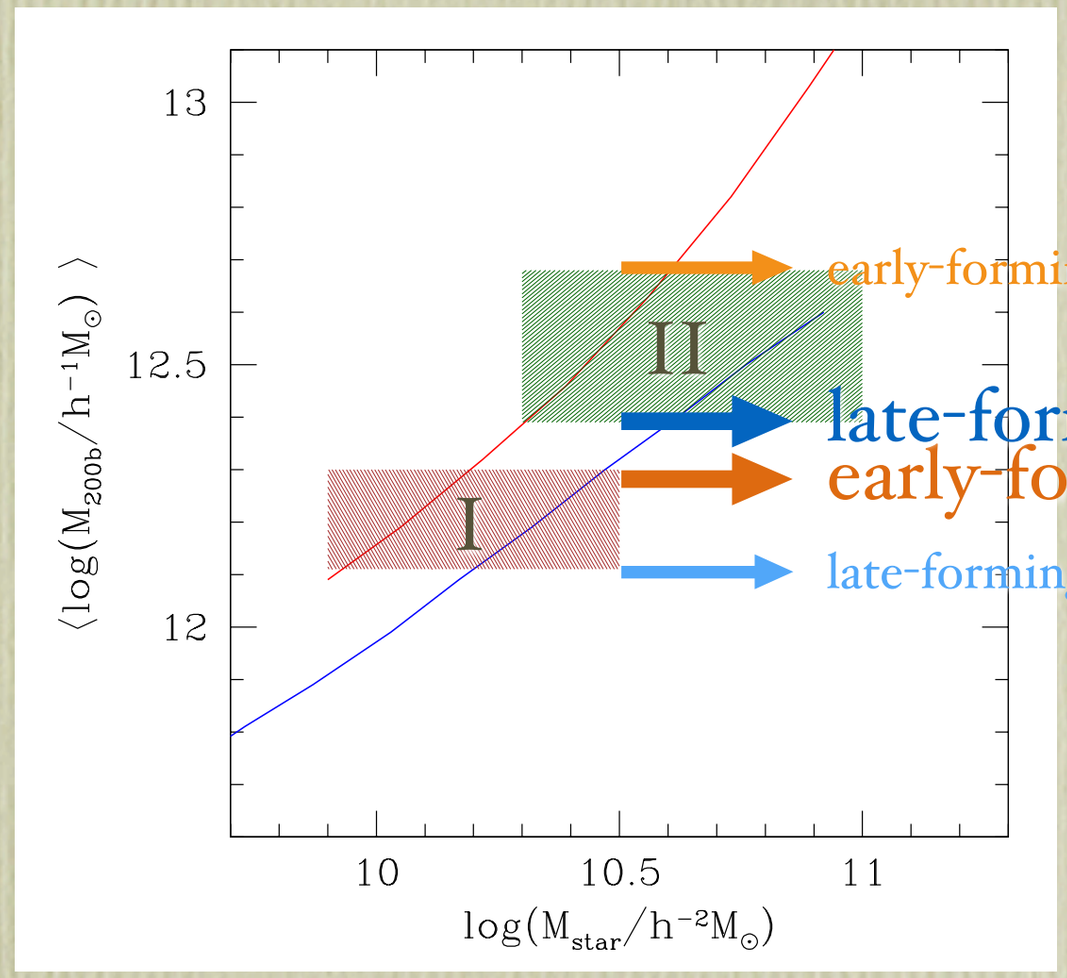


repeating Yang

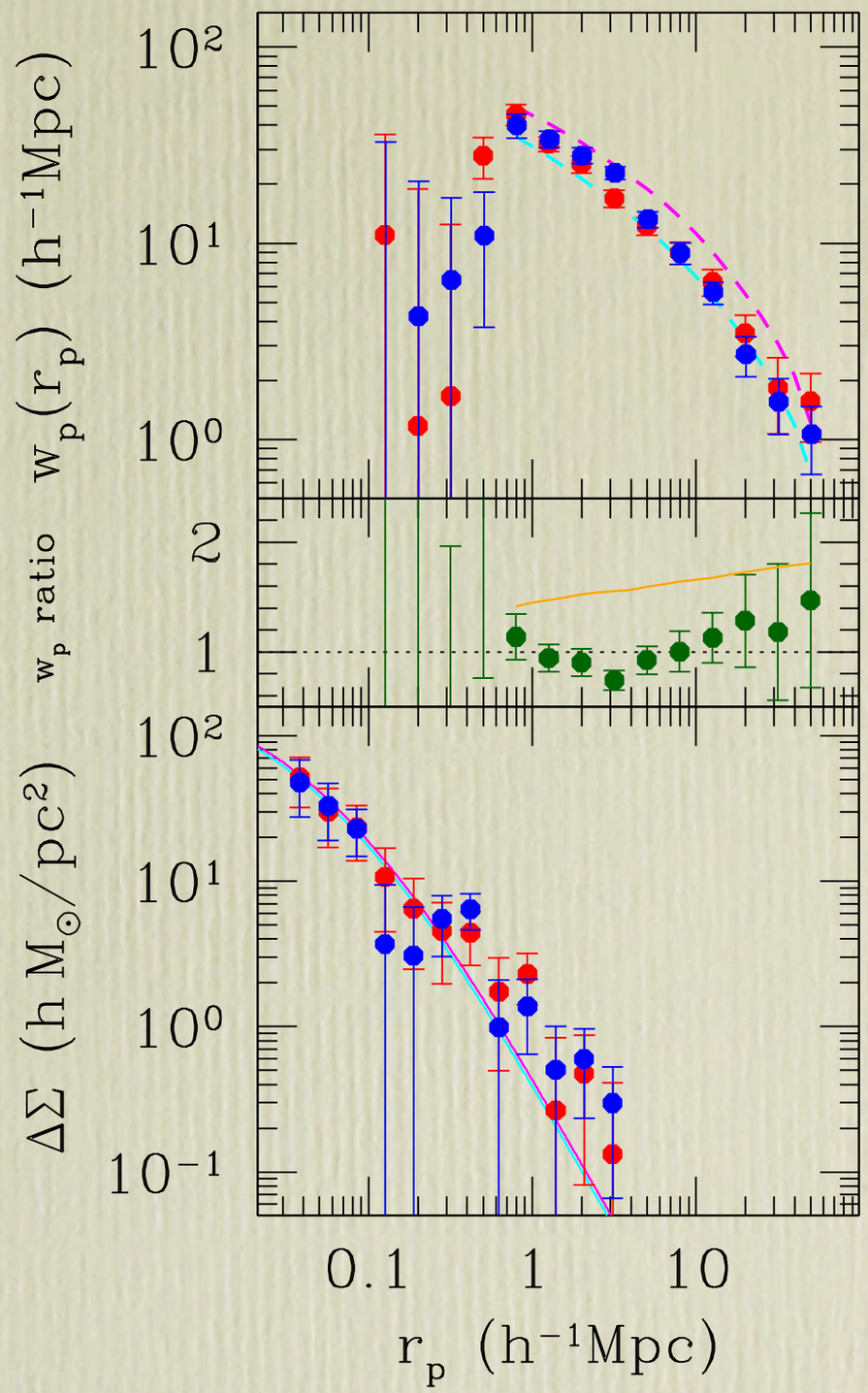
- using centrals with log M_{Yang}=12-12.5
- division for sSFR: 10^{-11} yr^{-1}
- lensing masses for sSFR samples
  - $(8.5\pm1.3)\times10^{11}h^{-1}M_{sun}$ (low sSFR)
  - $(4.5\pm0.9)\times10^{11}h^{-1}M_{sun}$ (high sSFR)
- lensing masses for SFH samples
  - $(9.2\pm1.7)\times10^{11}h^{-1}M_{sun}$ (early-forming)
  - $(2.7\pm1.6)\times10^{11}h^{-1}M_{sun}$ (late-forming)
- substantial satellite contamination!
- cannot attribute differences in bias (solely) to **ab**
- scatter in M_{Yang} *not* random, but rather correlates with sSFR/SFH!



two-step approach: SFH sample

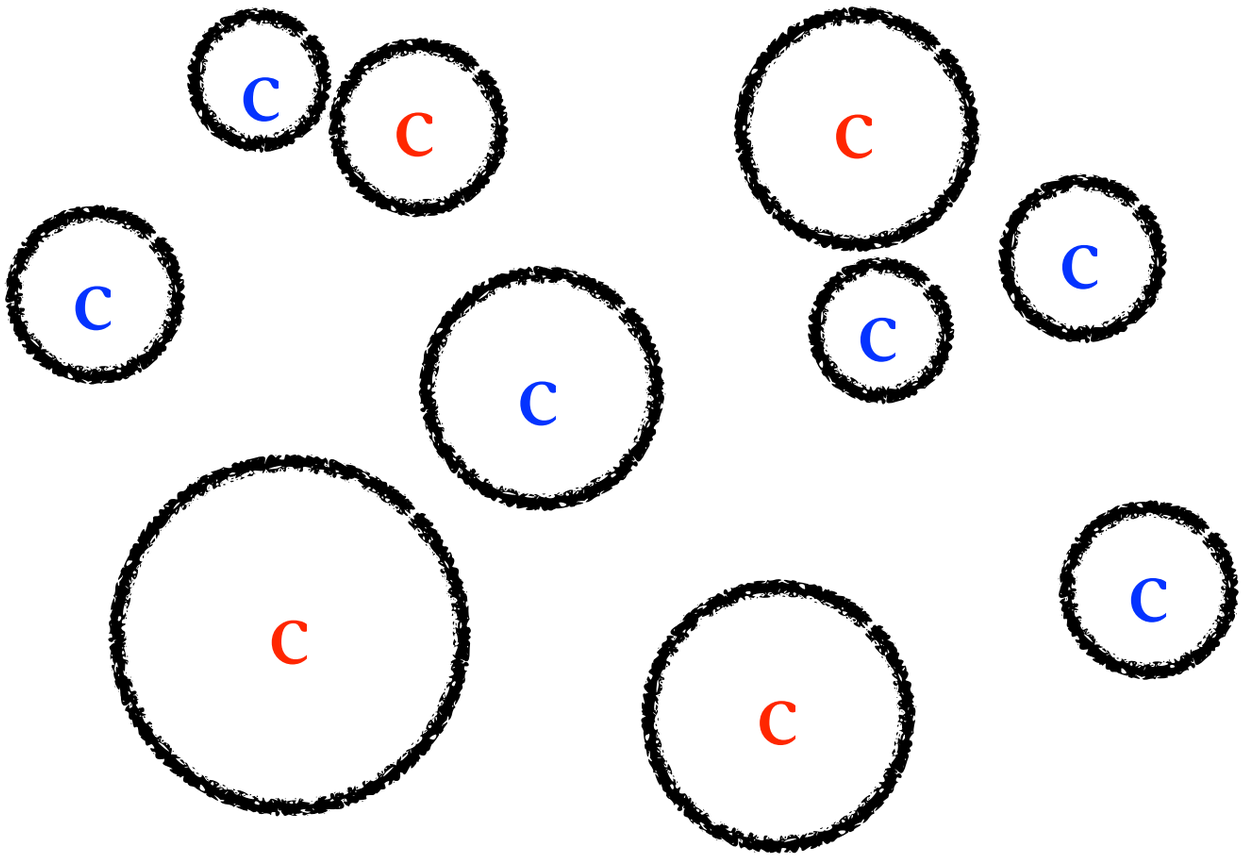


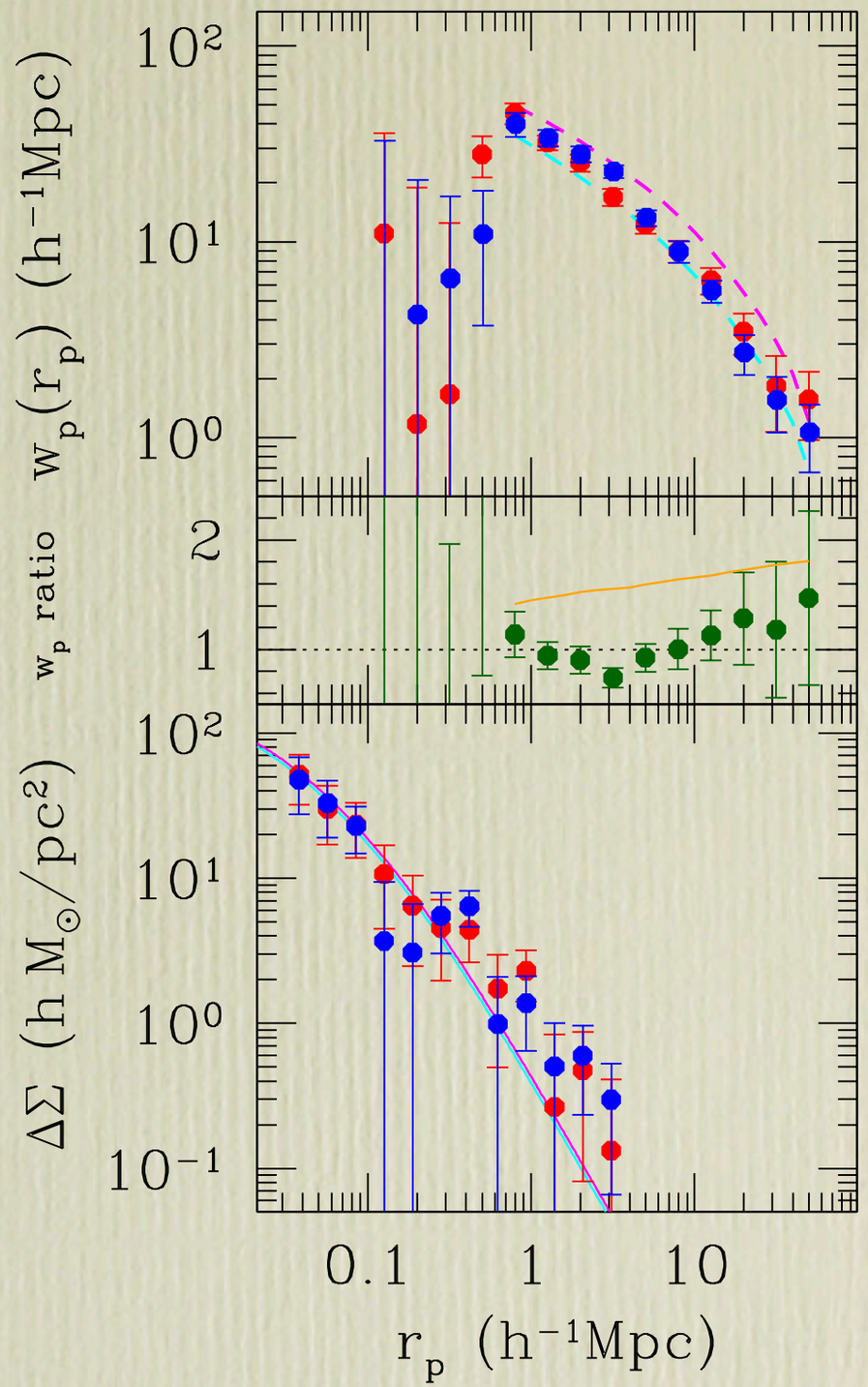
- start with central galaxy stellar mass—halo mass relations for red & blue galaxies (More+11)
- take early-forming subsample from a "low" mass sample, and late-forming subsample from a "high" mass sample



two-step approach: SFH sample

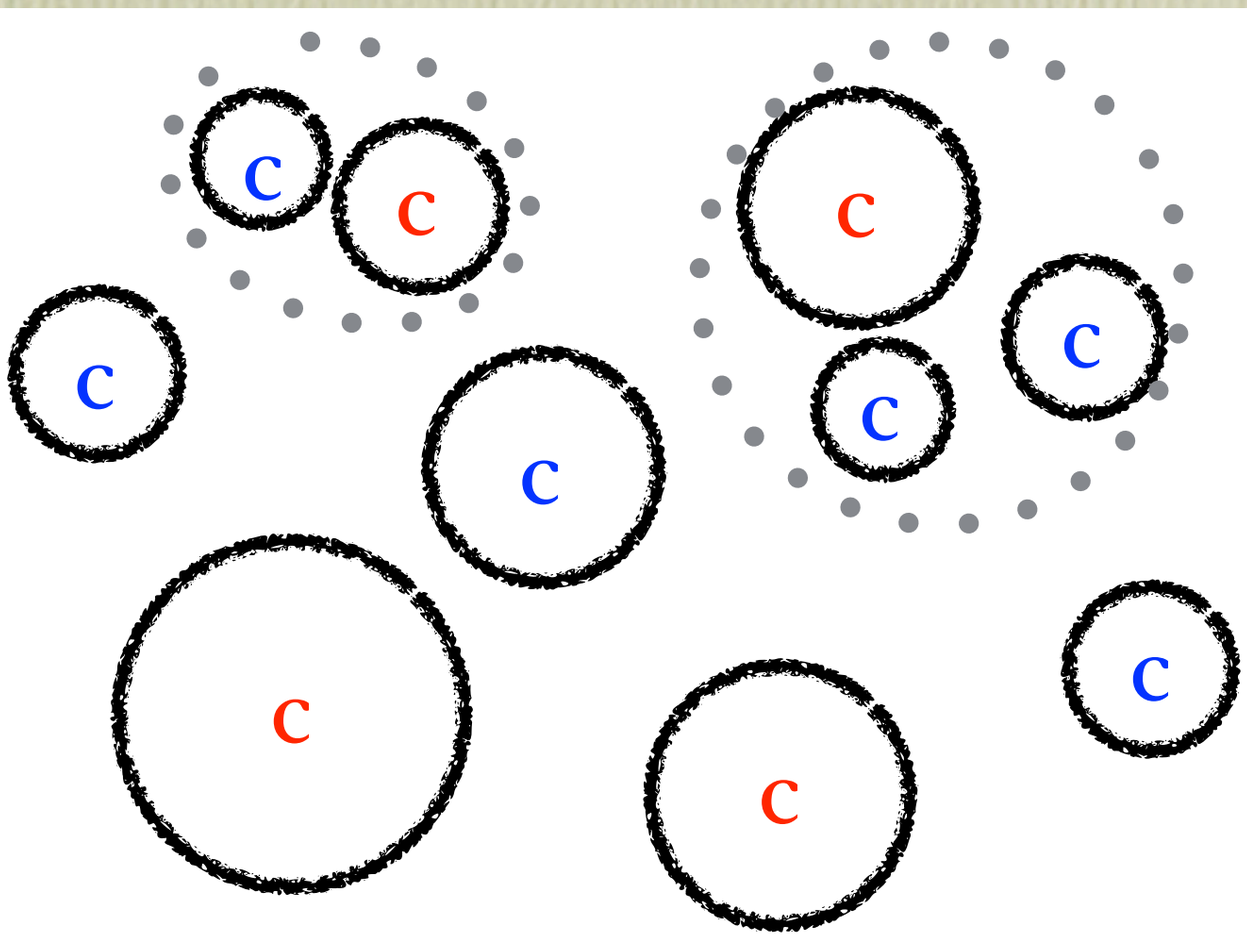
- need to take out satellites lurking in the central sample, using a friends-of-friends (FoF) code (removing ~10% of galaxies)
- lensing masses
  - $(9.1\pm2.4)\times10^{11}\ h^{-1}M_{sun}$
  - $(8.2\pm2.2)\times10^{11}\ h^{-1}M_{sun}$

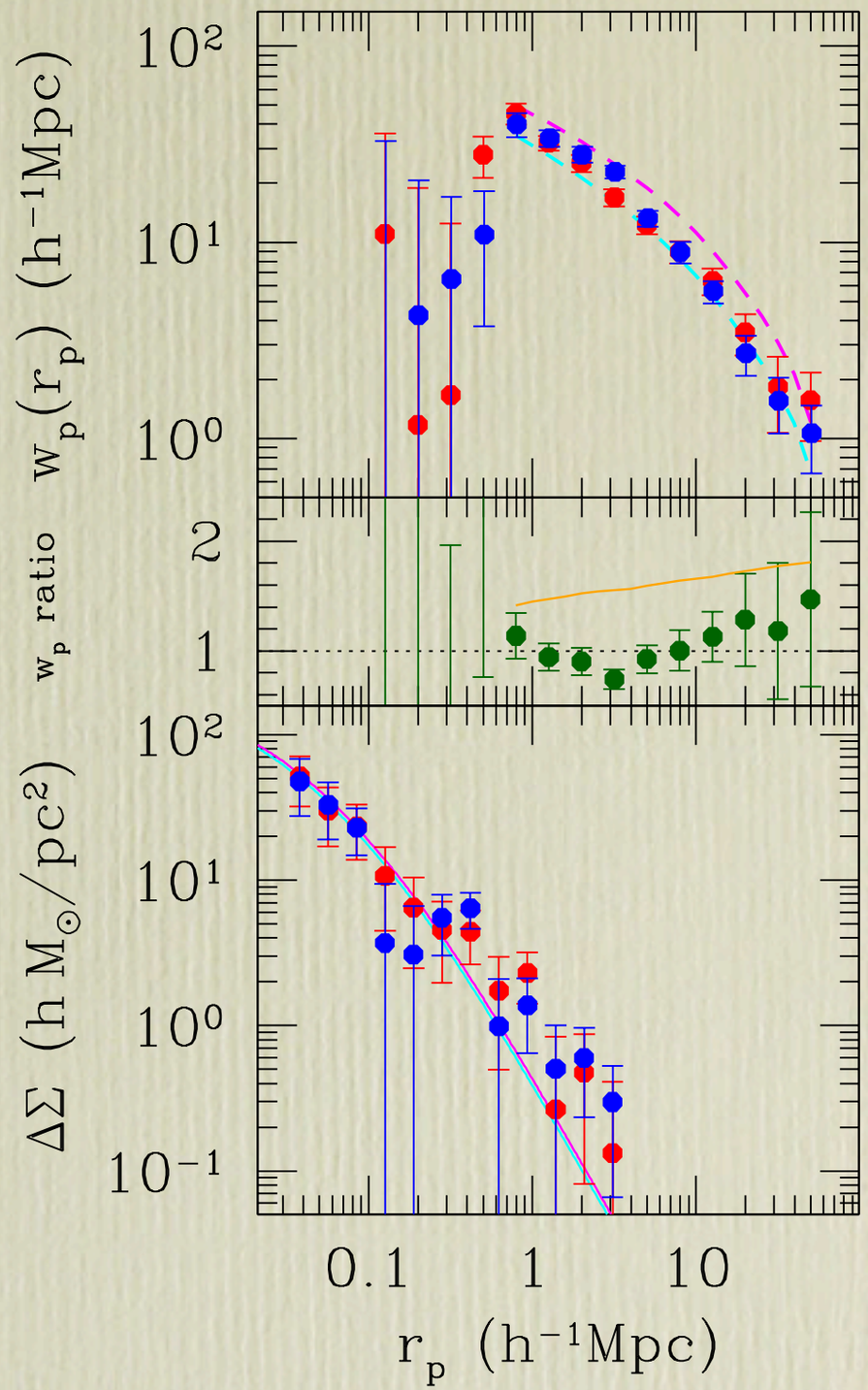




two-step approach: SFH sample

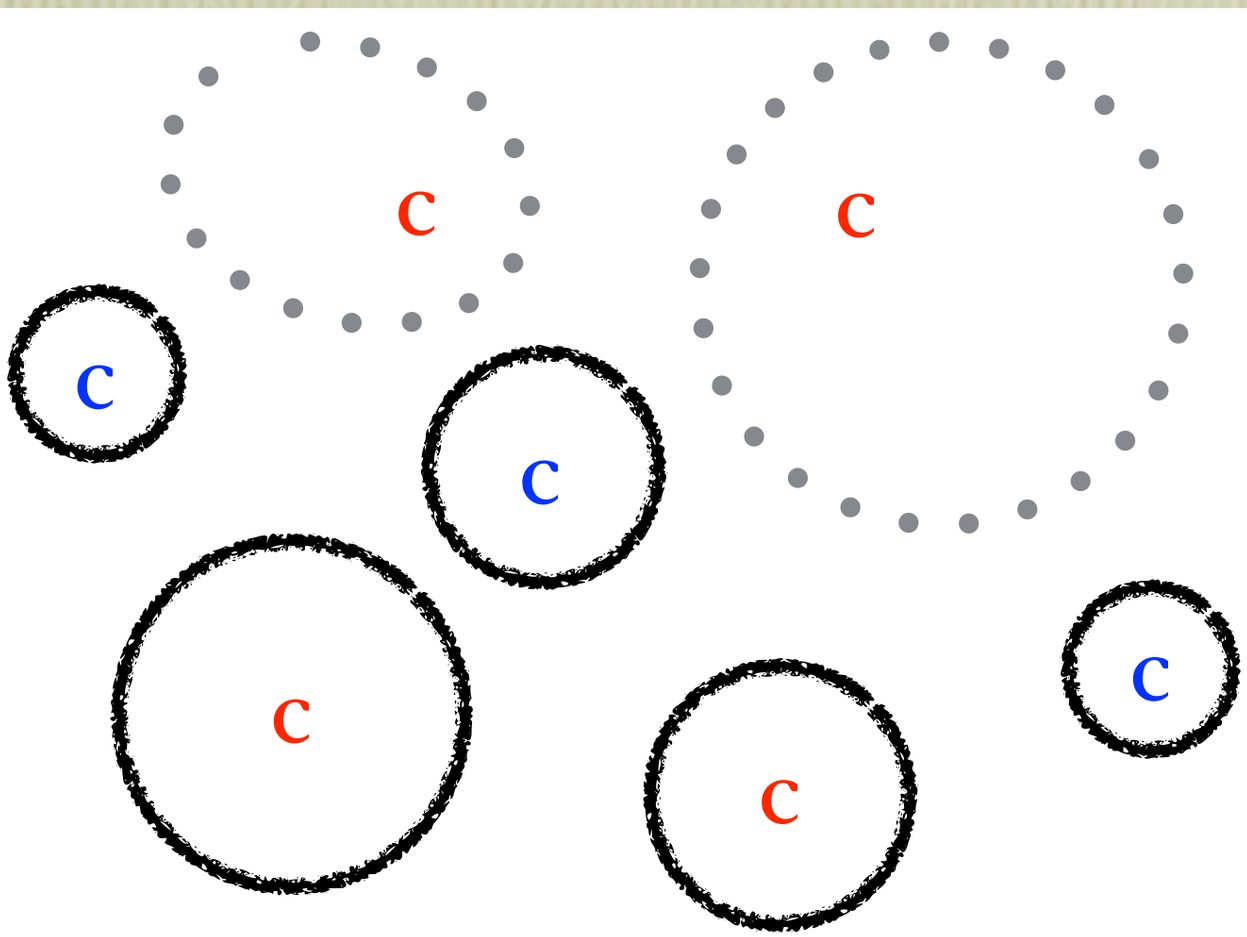
- need to take out satellites lurking in the central sample, using a friends-of-friends (FoF) code (removing ~10% of galaxies)
- lensing masses
  - $(9.1\pm2.4)\times10^{11}\ h^{-1}M_{sun}$
  - $(8.2\pm2.2)\times10^{11}\ h^{-1}M_{sun}$

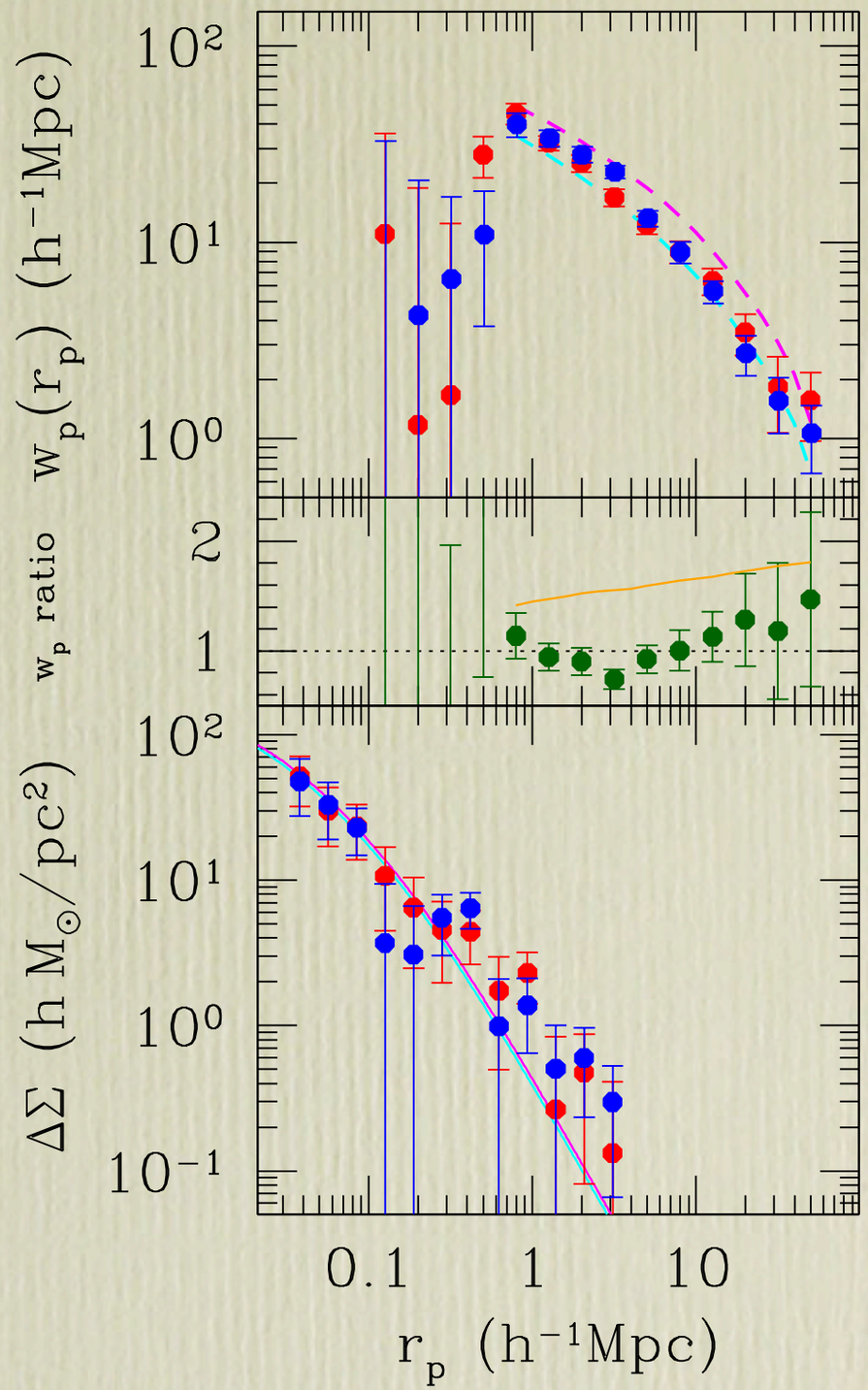




two-step approach: SFH sample

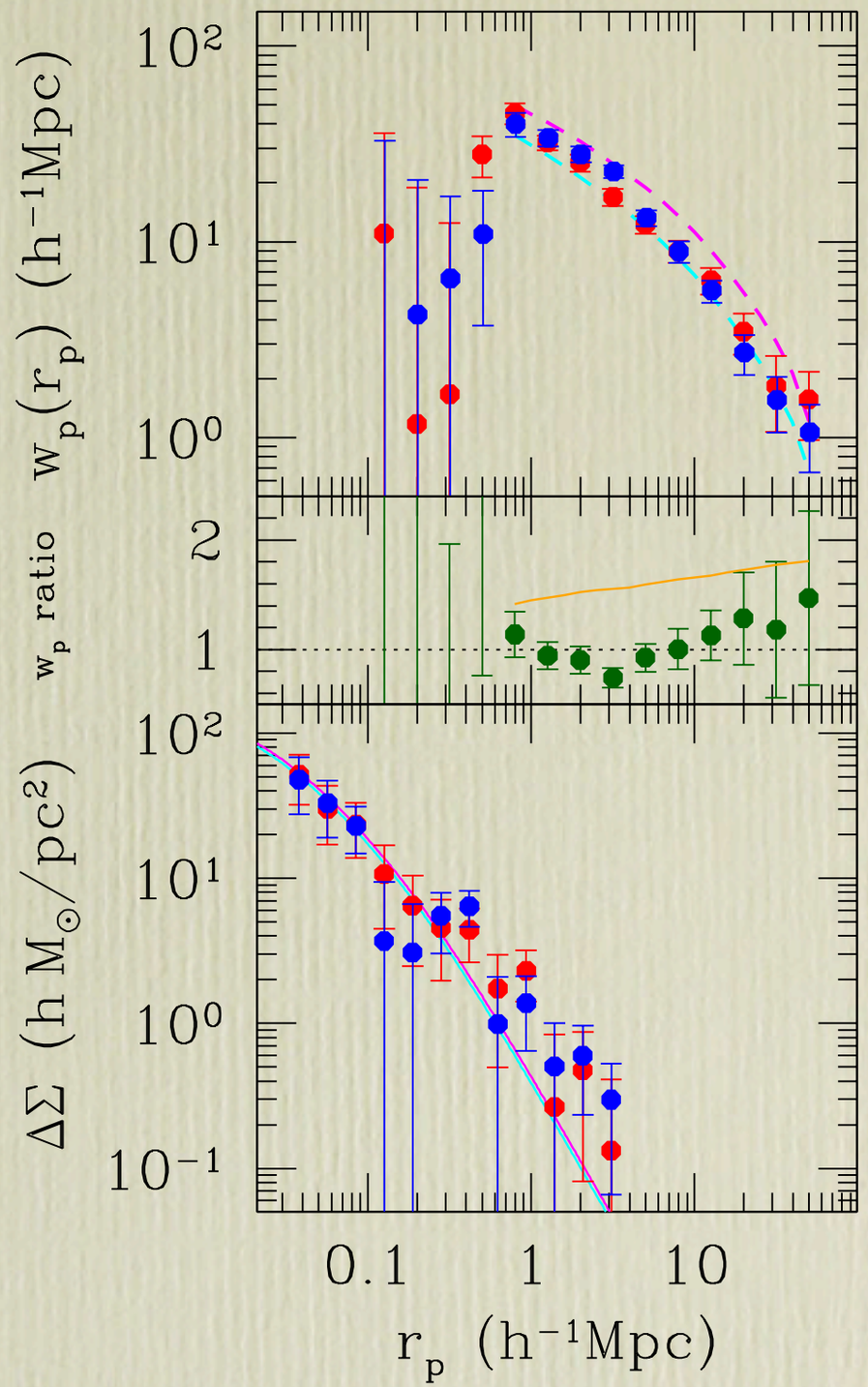
- need to take out satellites lurking in the central sample, using a friends-of-friends (FoF) code (removing ~10% of galaxies)
- lensing masses
  - $(9.1\pm2.4)\times10^{11}\ h^{-1}M_{sun}$
  - $(8.2\pm2.2)\times10^{11}\ h^{-1}M_{sun}$



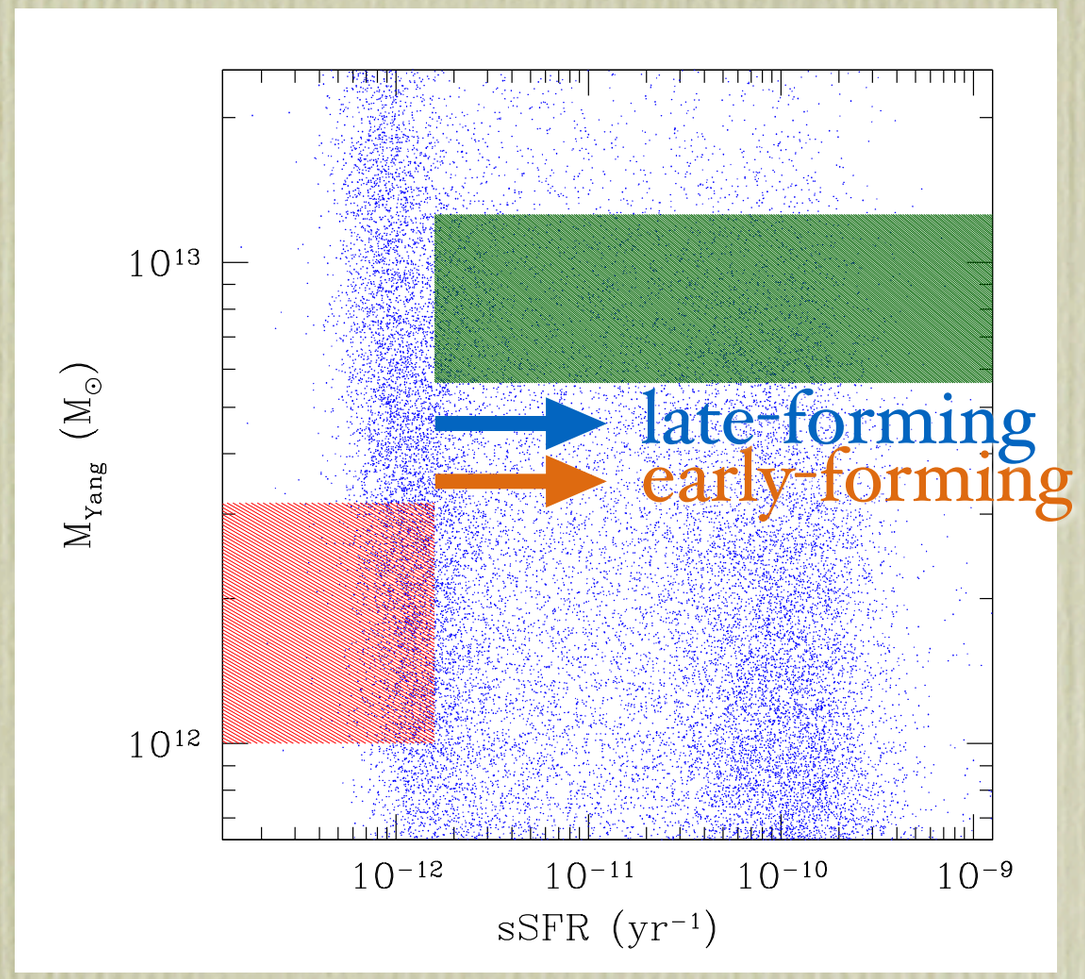


two-step approach: SFH sample

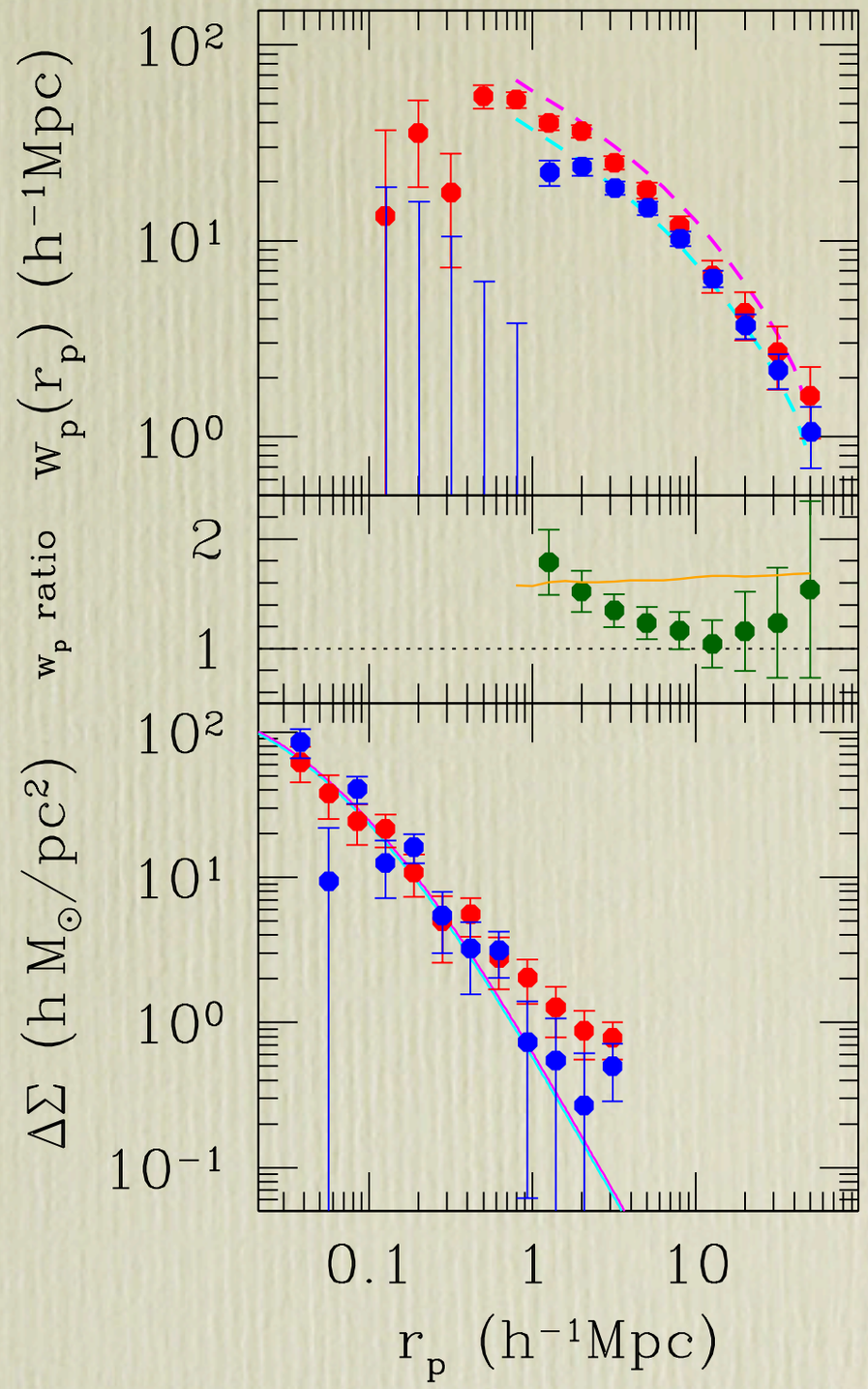
- need to take out satellites lurking in the central sample, using a friends-of-friends (FoF) code (removing ~10% of galaxies)
- lensing masses
  - $(9.1\pm2.4)\times10^{11}\ h^{-1}M_{sun}$
  - $(8.2\pm2.2)\times10^{11}\ h^{-1}M_{sun}$
- at 5-35 h^{-1}Mpc, relative bias is $b_{rel}=1.00\pm0.12$
- assuming halo mass distribution of our samples follows log-normal form, consider possible M_{cen} & σ_{logM} combinations that match the observed $\Delta\Sigma$ to produce the theoretical expectations
- observed and theoretical b_{rel} consistent at 2.6×10^{-6} level



two-step approach: sSFR sample

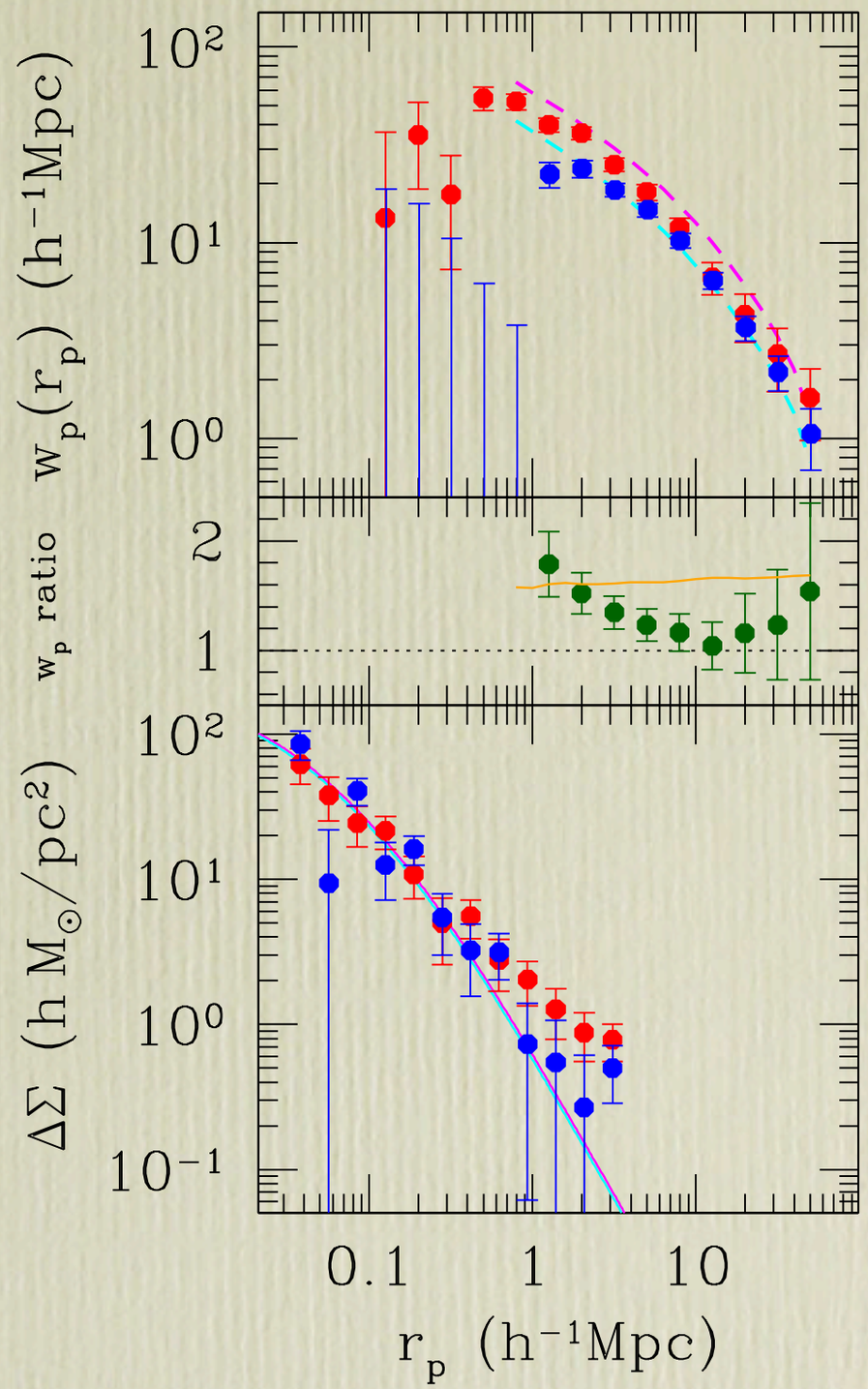


- using M_{Yang} as initial guesses, adjust ranges for high- and low-sSFR samples until lensing masses agree
- applying FoF satellite removal



two-step approach: sSFR sample

- lensing masses
  - $(1.3\pm0.2)\times10^{11}\ h^{-1}M_{sun}$
  - $(1.2\pm0.2)\times10^{11}\ h^{-1}M_{sun}$
- at 5-35 h^{-1}Mpc, relative bias is $b_{rel}=1.07\pm0.14$
- compare with theoretical expectation from age-matching model (Watson+15)
- consider possible M_{cen} & σ_{logM} combinations that match the observed $\Delta\Sigma$ to produce the theoretical expectations
- observed and theoretical b_{rel} consistent at 2.5×10^{-4} level
- no evidence of **ab** from either SFH or sSFR samples



implications

- galaxy formation processes render **ab** magnitude small?
  - not according to Guo+11 semi-analytic model
- *VESPA*-based SFH and SDSS-based sSFR not good enough for subtle effect like **ab**?
  - may need higher S/N spectral data from future surveys
- better proxy for halo formation time?
  - z_{mah} derived for SFH or mean stellar age
  - R_{mem} as suggested by Miyatake+15
  - look at extrema of the distributions

implications

- use the Yang et al group catalog with caution!
  - scatter is *not* random, but rather correlates with physical properties of galaxies (e.g., SFH, sSFR)
  - central/satellite designation not perfect (~10% contamination)
  - halo mass estimates may be biased due to presence of satellites (in massive halos)