Connecting the physical properties of galaxies with their spatial and velocity distributions

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Outline

Motivation

How to test LSS formation models using observations?

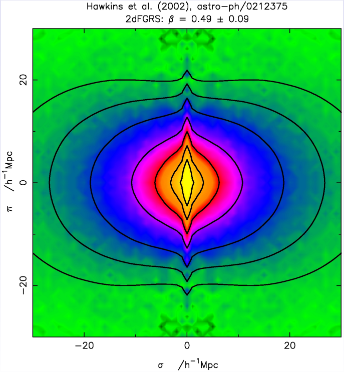
(a) Probes	(b) Statistics
Galaxy distribution	CF, power spectrum
Peculiar velocities of galaxies	PVD
CMB	
Gravitational lensing	

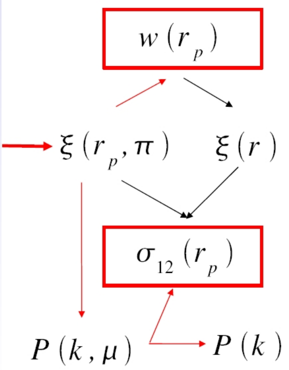
How to test models of galaxy distribution and formation?

- Linking physical properties of galaxies with their DM haloes
- Methods:
  HOD, N-body/hydro simulations, Semi-analytic models

Statistics of redshift Surveys

- Redshift space distortion: deviate from real positions because of peculiar velocities
- Redshift space 2PCF: distorted!
- Statistics: $\xi(r_p, \pi) w_p(r_p, \pi) \xi(r)\ \sigma_{12}(r_p) \sigma_{12}(k) P(k)$





Statistics of redshift surveys

- Hamilton (1993) estimator of $\xi(r_p, \pi)$:

$$\xi(r_p, \pi) = \frac{4DD(r_p, \pi)RR(r_p, \pi)}{[DR(r_p, \pi)]^2} - 1. \tag{1}$$

- $\xi(r_p, \pi) \longrightarrow \sigma_{12}(r_p)$:

$$\xi(r_p, \pi) = \int f(v_{12})\xi\left(\sqrt{r_p^2 + (\pi - v_{12})^2}\right) dv_{12}, \tag{2}$$

$$f(v_{12}) = \frac{1}{\sqrt{2}\sigma_{12}(r)} \exp\left(-\frac{\sqrt{2}}{\sigma_{12}(r)} \left|v_{12} - \overline{v_{12}}(r)\right|\right) \tag{3}$$

- $P(k, \mu) \longrightarrow P(k), \sigma_{12}(k)$:

$$P(k, \mu) = P(k)(1 + \beta\mu^2)^2 D(k\mu\sigma_{12}(k)). \tag{4}$$

$$D(k\mu\sigma_{12}(k)) = \frac{1}{1 + \frac{1}{2}k^2\mu^2\sigma_{12}(k)^2}\,. \tag{5}$$

Current status

The spatial distribution of galaxies

- 2PCF: close to a power law with $\gamma \approx -1.8$
- A scale-dependent bias relative to dark haloes: galaxy efficiency depends on halo mass
- Galaxy clustering depends on luminosity, colour, spectral type, morphology type

The velocity distribution of galaxies

- PVD$\sim$ 600km/s at $1h^{-1}$Mpc
- also a bias relative to dark haloes
- dependence on luminosity: bimodal $\longrightarrow$ quite a fraction of faint galaxies must be in high mass haloes!

Questions

From luminosity and colour to stellar mass, structure and mean stellar age?

- L is not always tightly correlated with M_*
- L and colour strongly depend on the fraction of young stellar populations: M_*/L evolves

Structure, star formation history

- Does the surounding environment affect them in the same way?

Constrains on galaxy formation models

- Can current SAMs reproduce simultaneously the LF, CF and PVD?
- The bimodal nature of PVD?

Our approach

Procedure

- Select subsamples according to physical quantities, and compute 2PCF and PVD for each of them
- Construct mock catalogues of the SDSS and compare with observations

Physical quantities

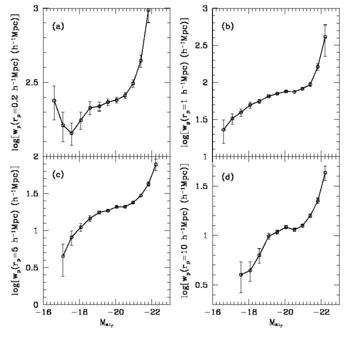
- $M_{^{0.1}r}$, M_*
- Recent SFH: $g - r$, D_{4000}
- Structure: $C = R_{90}/R_{50}$, $\mu_* = M_*/2\pi r_{50,z}^2$

Data

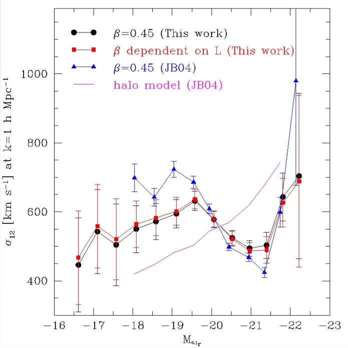
- NYU-VAGCBlanton et al. (2005)
- HJU/MPA SDSS DataBrinchman et al. (2004)

Luminosity dependence

- $w_p(r_p)$: increases with L^*
- $\sigma_{12}(k)$: bimodal on small scales, minimum at L^*
- $\sigma_{12}(k)$: consistent with 2dFGRS



(a) $w_p(r_p)$

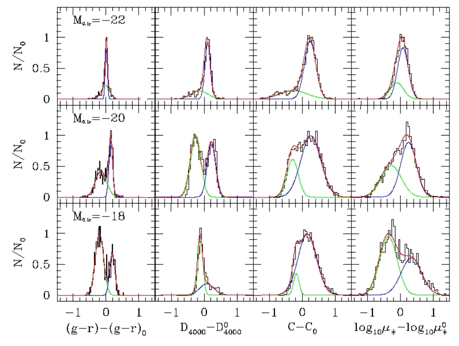


(b) $\sigma_{12}(k)$

Dependence on physical properties

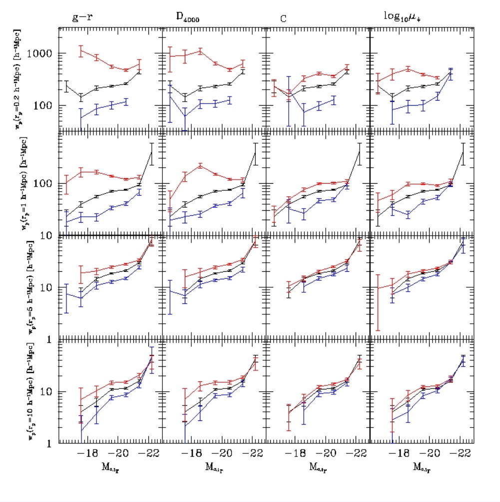
Galaxy classification

- Bi-Gaussian distributions
- Divider: the median of the two Gaussian centres



(a) Bi-Gaussian

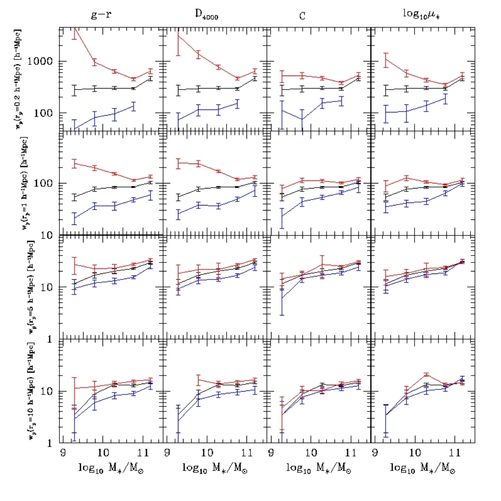
Dependence on physical properties



$w_p(r_p)$ vs L

- "red": more clustered
- significant on small scales and for faint galaxies
- more strongly dependent on SFH parameters
- dependence out to large scales

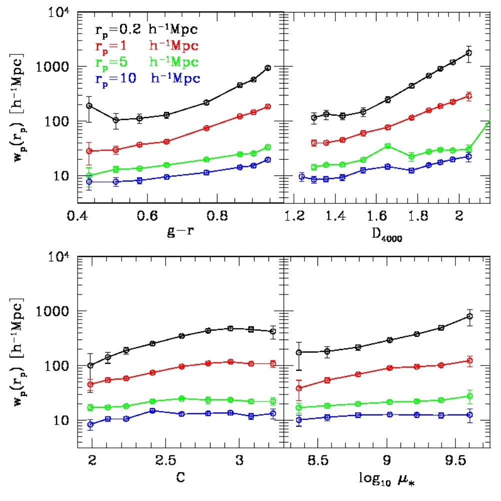
Dependence on physical properties



$w_p(r_p)$ vs. M_*

- Similar to the case of L
- more significant on small scales
- less significant on large scales

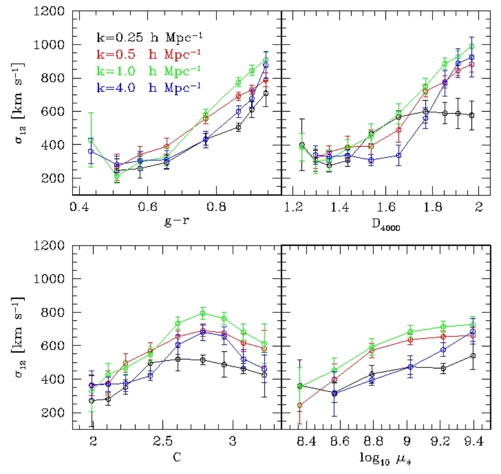
Dependence on physical properties



fixed M_*: $w_p(r_p)$ vs physical quantities

- dependent on $g - r/D_{4000}$ on large scales
- qualitary difference on small scales for the two kinds of parameters

Dependence on physical properties

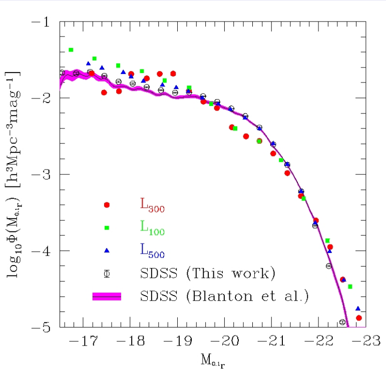


fixed M_*: $\sigma_{12}(k)$ *vs* physical quantities

- Reddest, intermediate C: strongest gravatational field, rich clusters
- blue, recent SF, diffuse structure: field galaxies

Galaxy catalogues by SAMs

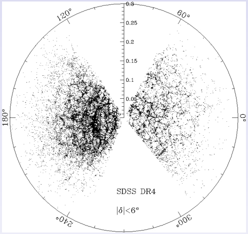
- Kang et al. (2005, K05)
  $\Omega_M = 0.3, \Omega_\Lambda = 0.7, L_{box} = 100h^{-1}\text{Mpc}$, $L_{box} = 300h^{-1}\text{Mpc}$
- Croton et al. (2006, C06)
  $\Omega_M = 0.25, \Omega_\Lambda = 0.75, L_{box} = 500h^{-1}\text{Mpc}$



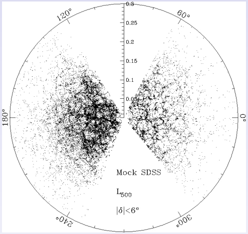
⟵ Luminosity function

- consistent with SDSS
- too many faint and bright galaxies

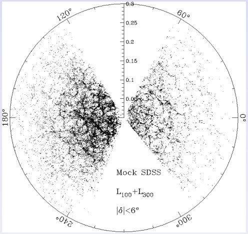
Constructing mock catalogues of SDSS DR4



(a) SDSS DR4

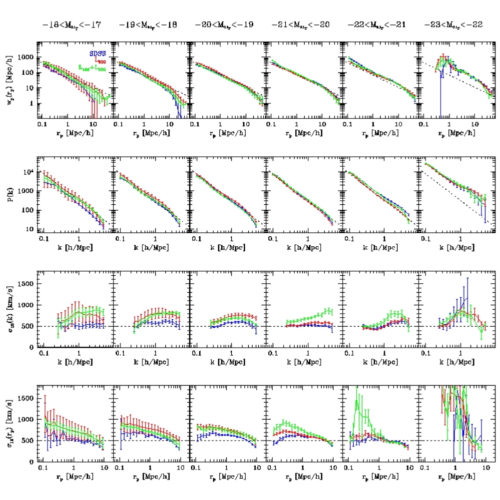


(b) L_{500}



(c) $L_{100} + L_{300}$

Comparisons with observations



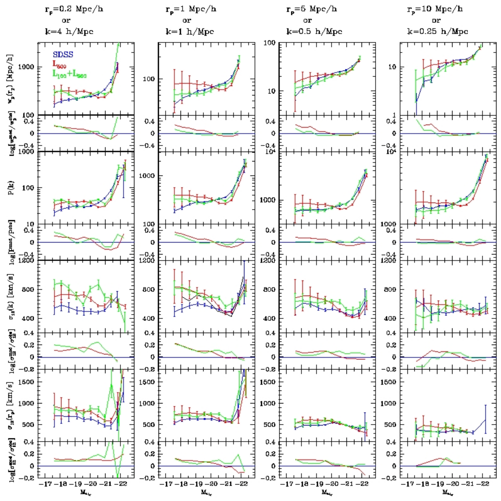
Clustering *vs* L

- better at the bright end
- for those fainter than -19: overestimated on small scales
- Cosmic variance

PVD *vs* L

- Similar to clustering results
- K05: larger Ω_M

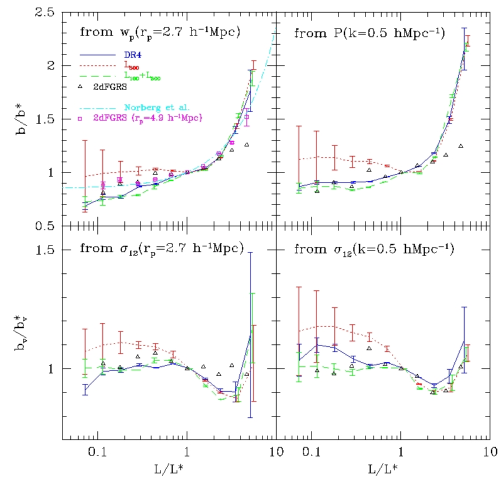
Comparison with observations



Scale dependence

- Clustering: K05 is better
- PVD: C06 is better
- PVD: bimodal shape reproduced!

Comparisons with observations



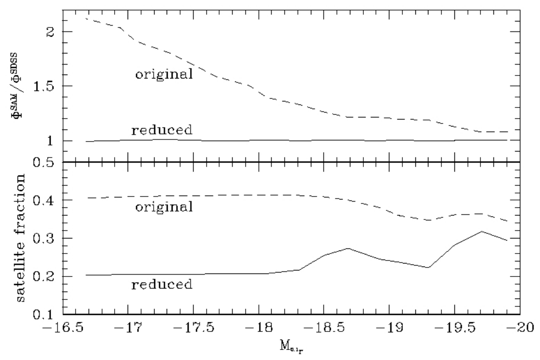
Relative bias factor

- $r_p = 2.7$Mpc/h
  $k = 0.5$h/Mpc
- K05 agree well
- C06: overestimated at the faint end
- $\Omega_M^{0.6}\sigma_8 = 0.3^{0.6} \times 0.9/1.3 \approx 0.33$
- difference between 2dF and SDSS!

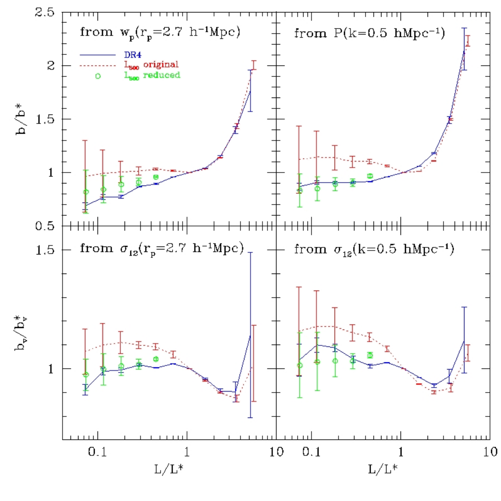
The faint end

Reduce the fraction of faint satellites

- Drop some faint galaxies ⟶ match the observed LF
- Preferentially drop satellites, but reduce by 50% at the most



The faint end



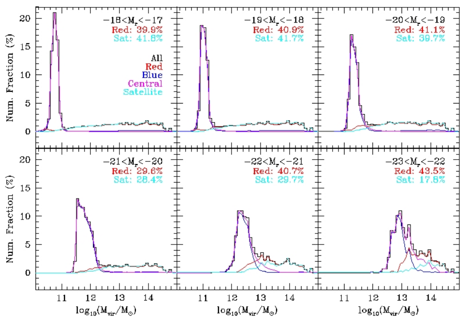
Relative bias factor

- come into good agreement
- new requirement for models!

The bimodal nature of PVD

Halo mass distribution

- bimodal: high-mass (satellites) well separated from low-mass haloes (central galaxies)
- Satellites: dominantly red
- A large fraction of faint galaxies reside in high-mass haloes!



Summary

Conclusions

- Clustering amplitude: increases with L (M^*), more sharply above L^*
  PVD decreases before increasing again $\longrightarrow$ quite a fraction faint red galaxies move in high-mass haloes
- Galaxies with redder colour, larger D_{4000}, more concentrated structure, and higher surface stellar mass density: more strongly cluster
- Clustering and PVD more strongly depend on recent SFH than on structure
  $\longrightarrow$ Different physical processes are required to explain environmental trends in star formation and in galaxy structure
- The reddest, intermediately concentrated galaxies move in the deepest gravatational fields.
  Galaxies with bluer colours, recent SF and more diffuse structure are likely field galaxies.

Summary

Conclusions

- The current galaxy formation models can reproduce the observed statistical properties not only of the spatial ditribution but also of the pairwise velocities as a function of luminosity, although there are still some subtle discrepancies.

Future work

- Comparison between observations and models:
  how about other physical properties?
- The faint end:
  observations need to be improved;
  If the overprediction of the clustering for faint galaxies is comfirmed, the SAMs may have to consider to reduce the fraction of faint satellite galaxies in massive halos.

THANK YOU!