

*Assembly bias & HOD formalism:
possible data constraints?
Preliminary results...*

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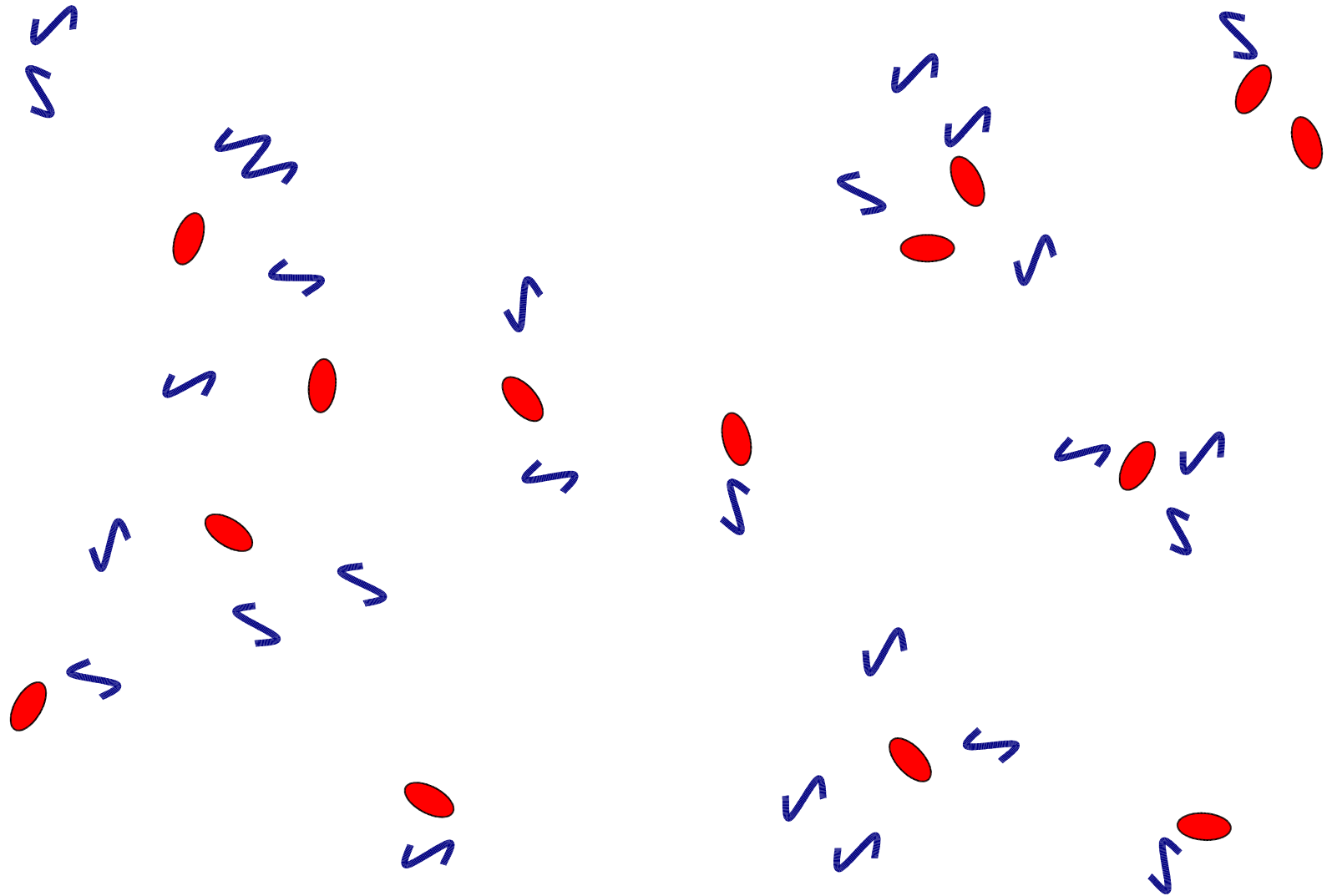
Contents

- *HOD models: short introduction*
- *Assembly bias: very brief description*
- *Are there possible data constraints, ie. to the level of current data from eg. SDSS or 2dFGRS.*

Quick intro to HOD formalism:

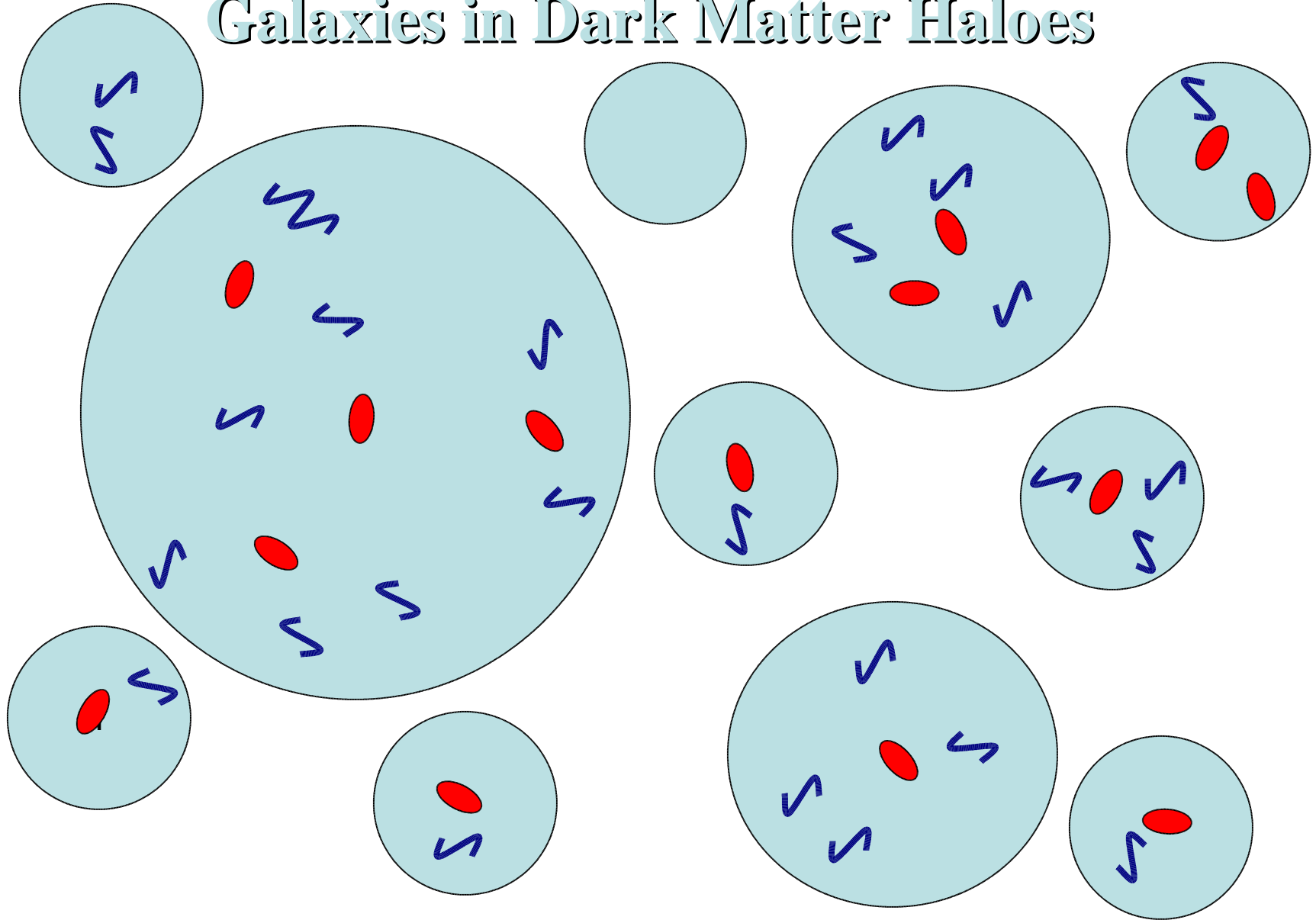
- Galaxies are expected to **form within DM halos** but a detailed understanding of the physics is still lacking
- The **number density** and **clustering properties** can be reliably computed as a **function of their halo mass**.
- It is therefore of great interest to try to establish a **connection between** these **DM halos** and different classes of **cosmic objects** (galaxies, quasars, etc.).
- This **phenomenological description** is useful to guide and **constrain galaxy formation models** and to **build mock catalogues** (to understand systematic effects in surveys).
- **Assumption: only halo mass, halo density profile & halo clustering matters!**

Galaxy Distribution: **ellipticals** & **spirals**



Galaxy Distribution: **ellipticals** & **spirals**

Galaxies in Dark Matter Haloes



The halo occupation distribution (HOD)

The key ingredient of the halo model for galaxy clustering is the **halo occupation distribution**, $P(N | M)$, which gives the probability for a halo of virial mass M to contain N galaxies of a given type.

In principle, its moment of order n can be determined by studying the n -point clustering properties of the galaxy population.

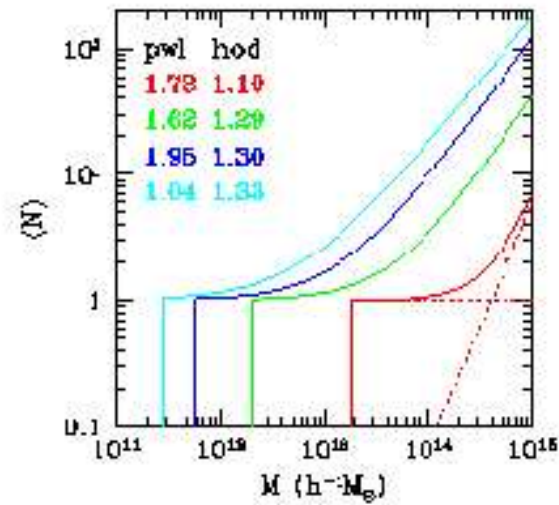
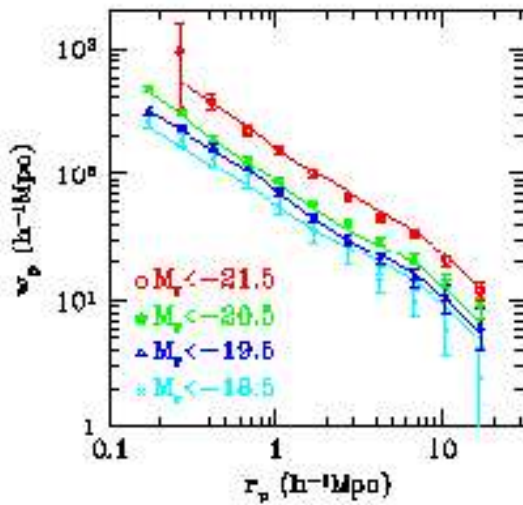
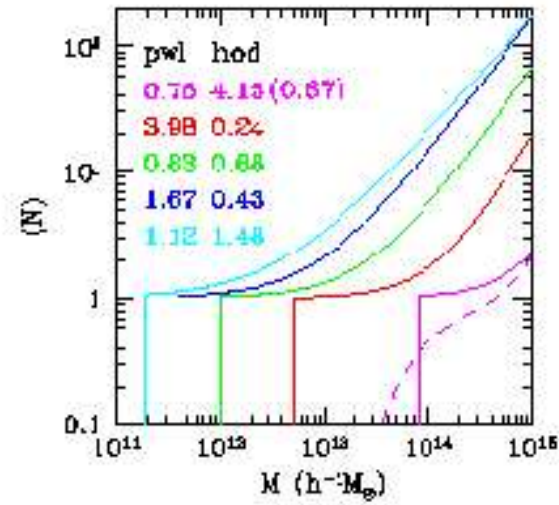
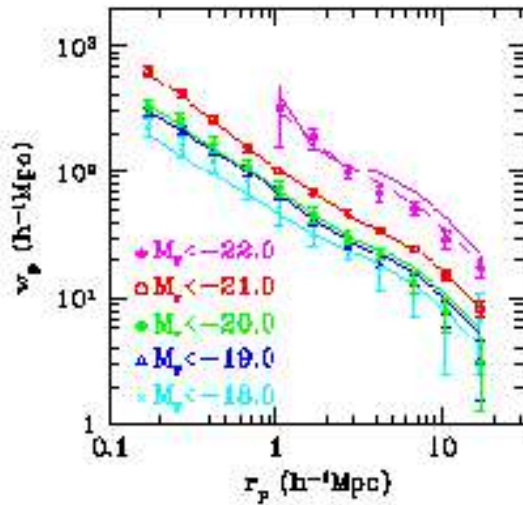
Some HONs (halo occupation number) used to describe galaxy & quasar samples:

$$1. N(M) = N_0 (M/M_0)^\alpha \Theta(M-M_0)$$

$$2. N(M) = N_0 \{ (M/M_0)^\alpha \Theta(M-M_0) + \Theta(M-M_{\min}) \}$$

$$3. N(M) = N_0 \{ \text{Exp}[-M_{\text{cut}}/(M-M_{\min})] (M/M_0)^\alpha + 1 \} \Theta(M-M_{\min})$$

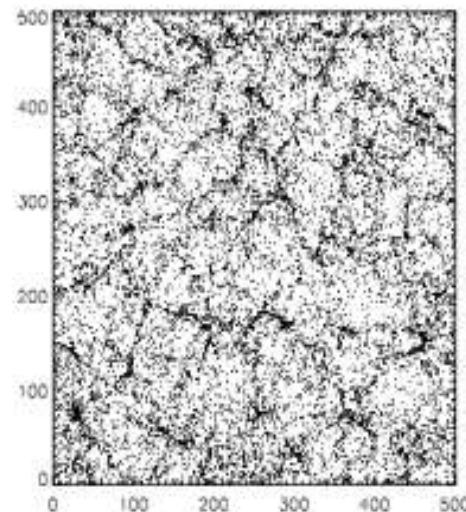
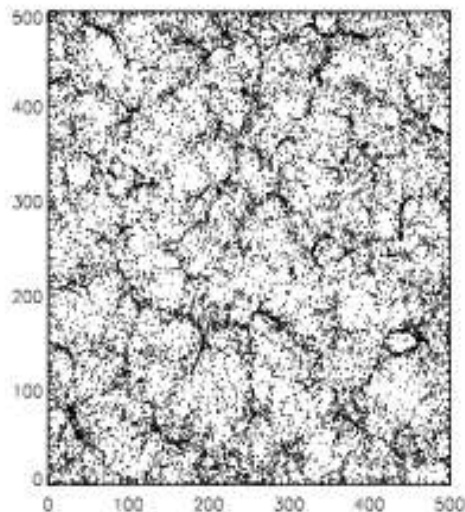
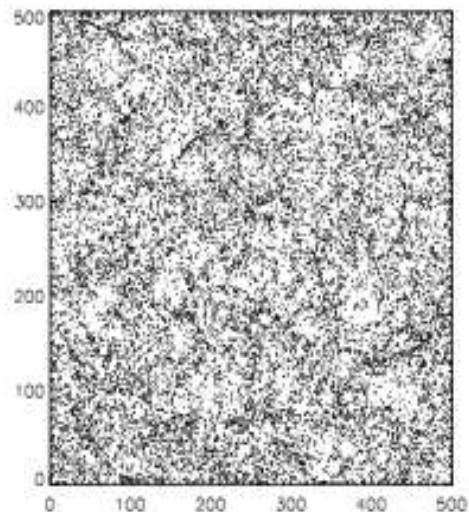
Context: Era of HOD model fitting



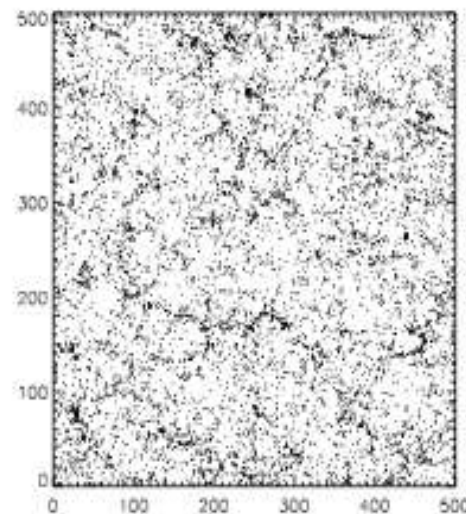
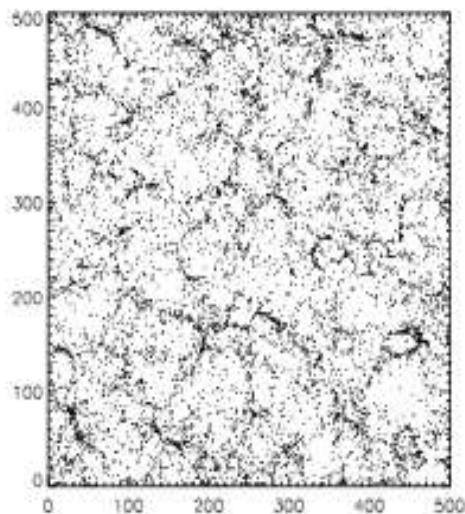
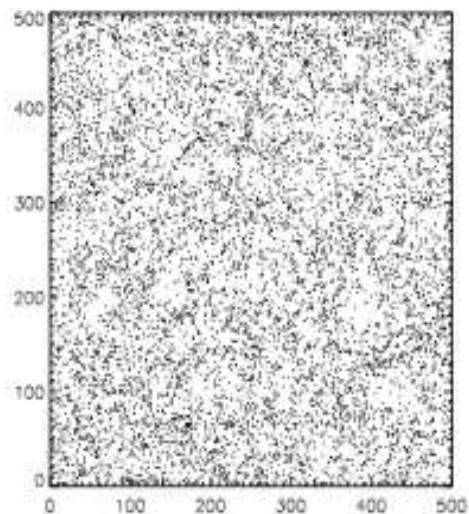
Context of assembly bias:

- *“Gao effect” (effect known already for several years...)
=> clustering properties of dark matter halos depend on formation time.*
- *Any imprint of this effect on galaxies?
=> assembly bias, ie. galaxy clustering depend not only on halo mass, but environment also.*
- *Does this imply HOD formalism becomes inappropriate for characterizing observations?*

Halo clustering: more than just M_h



Extreme
20%



Extreme
10%

Youngest Haloes

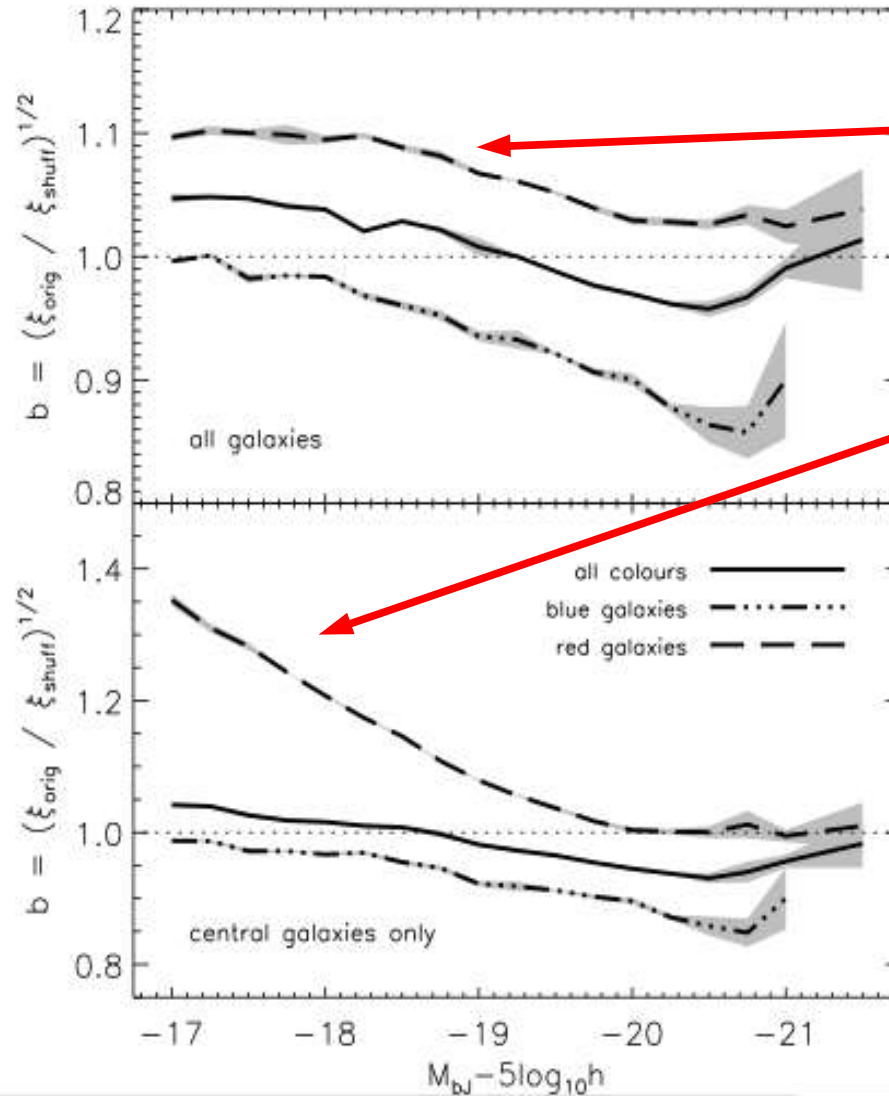
Oldest Haloes

Gao et al. (2006)

Context of assembly bias:

- *“Gao effect” (effect known already for several years...)
=> clustering properties of dark matter halos depend on formation time.*
- *Any imprint of this effect on galaxies?
=> assembly bias, ie. galaxy clustering depend not only on halo mass, but environment also.*
- *Does this imply HOD formalism becomes inappropriate for characterizing observations?*

Assembly bias: more than just M_h



Faint galaxies
more clustered
than shuffled
catalogue
 \Rightarrow assembly bias

Millennium simulation & semi-analytics...

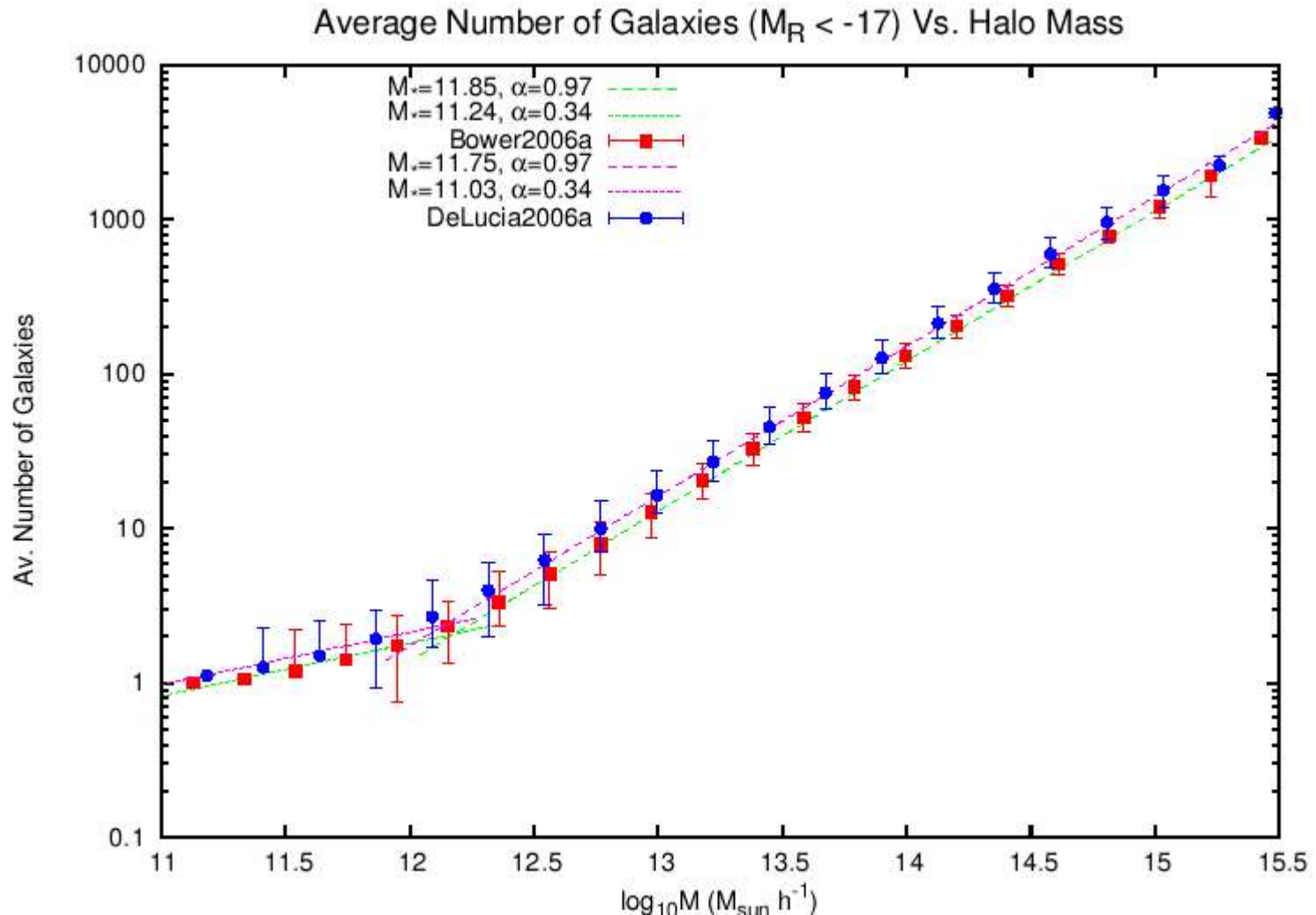
1. Two galaxy formation recipes:

De Lucia et al. (2006) & Bower et al. (2006)

2. Can either galaxy formation model be described by “standard” **HOD formalism**...

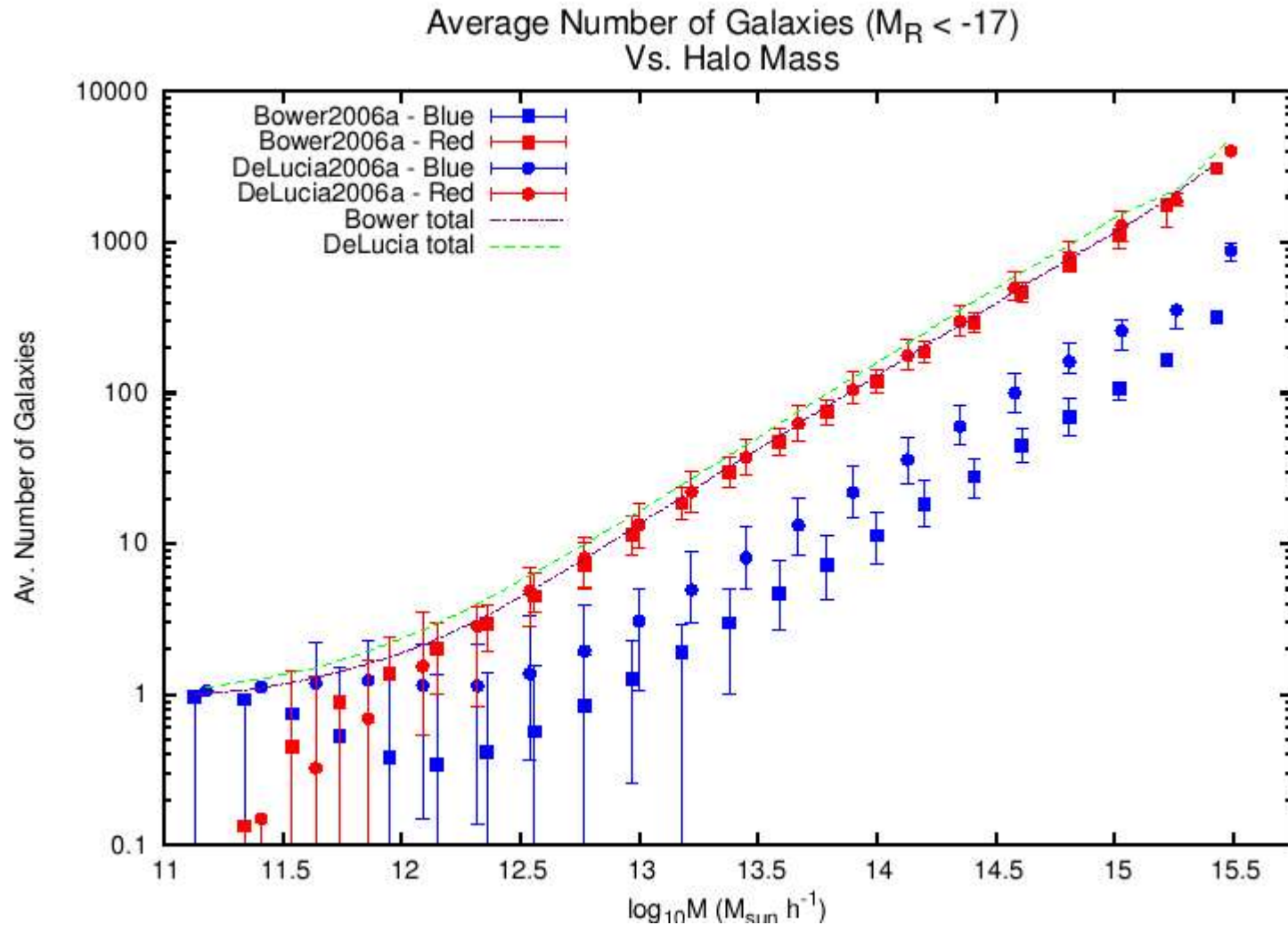
3. Split sample by **environment** and see effect on **HONs** as function of **galaxy luminosity and colour**.

$N(M)$ for galaxies brighter than $M_r \sim -17$



NB: the errors should be taken with a pinch of salt when effective numbers are small

... the same but split by colour ...

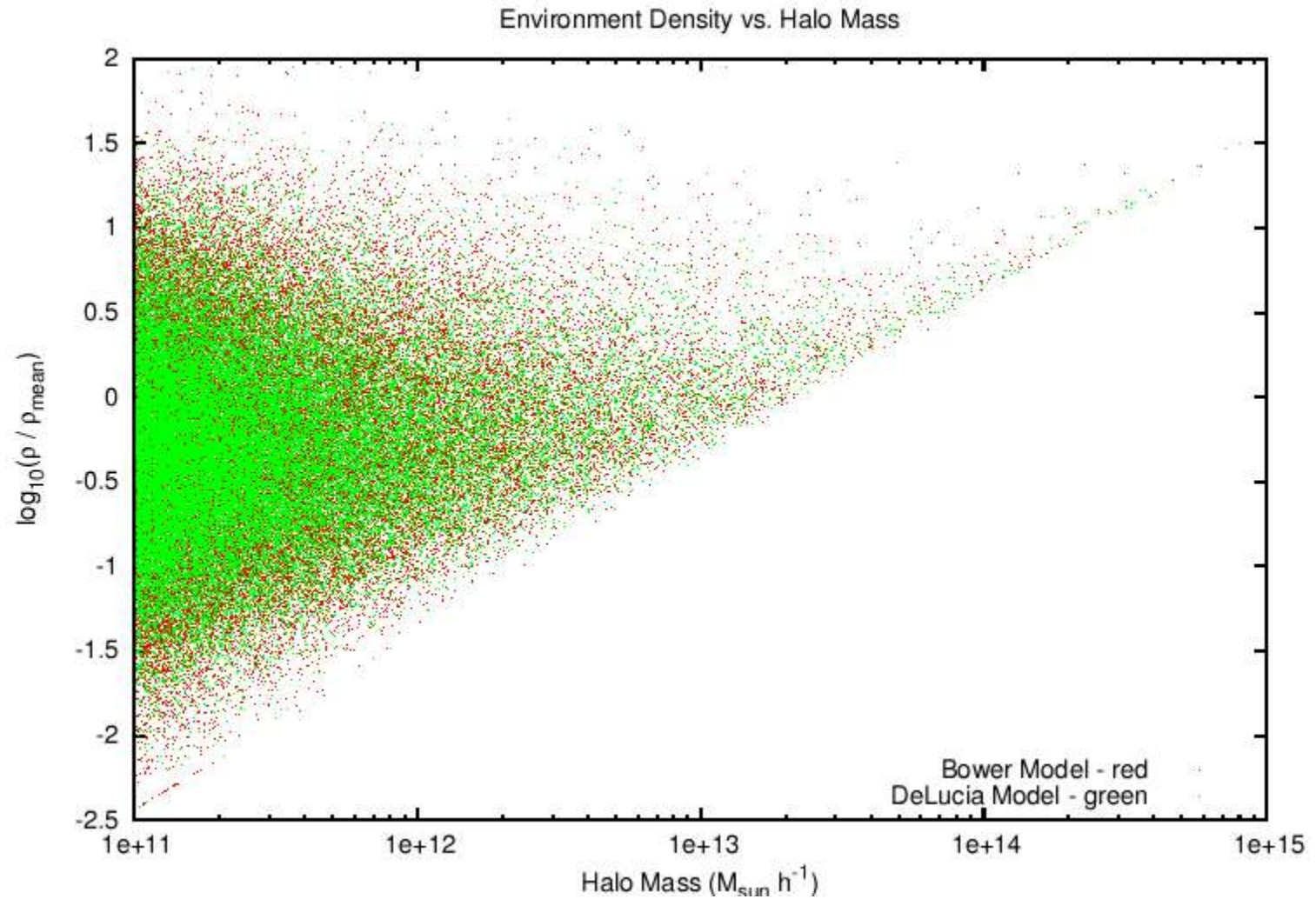


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Environment: quick & dirty definition...

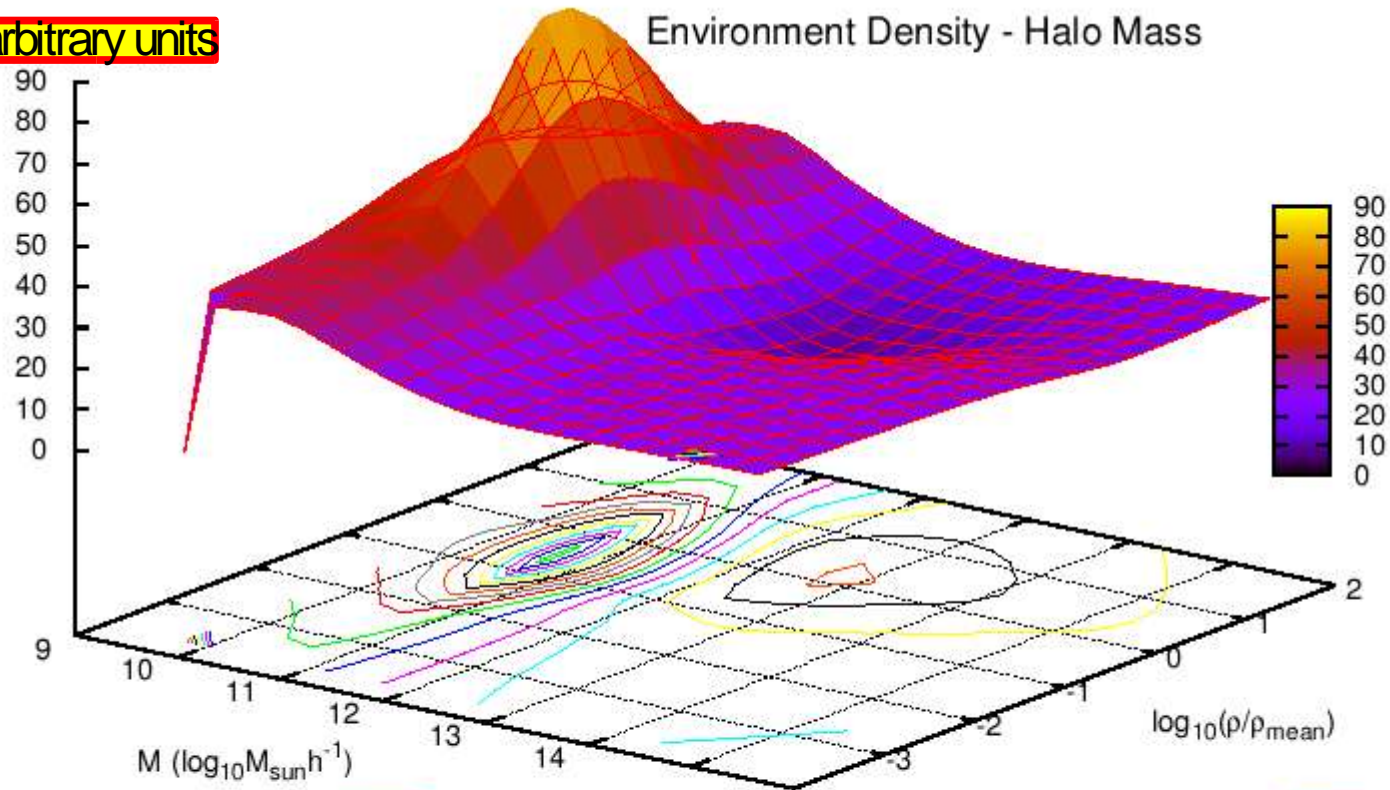
- Choose kernel and scale:
 - spherical top hat of 5 Mpc/h radius
- Choose density defining population:
 - halos (reduced to a point at the halo centre of mass)
- Choose weighting scheme:
 - virial mass weighted density
- Remember caveats of environment definitions in comparisons...

Environment: density vs halo mass...



Environment: density vs halo mass...

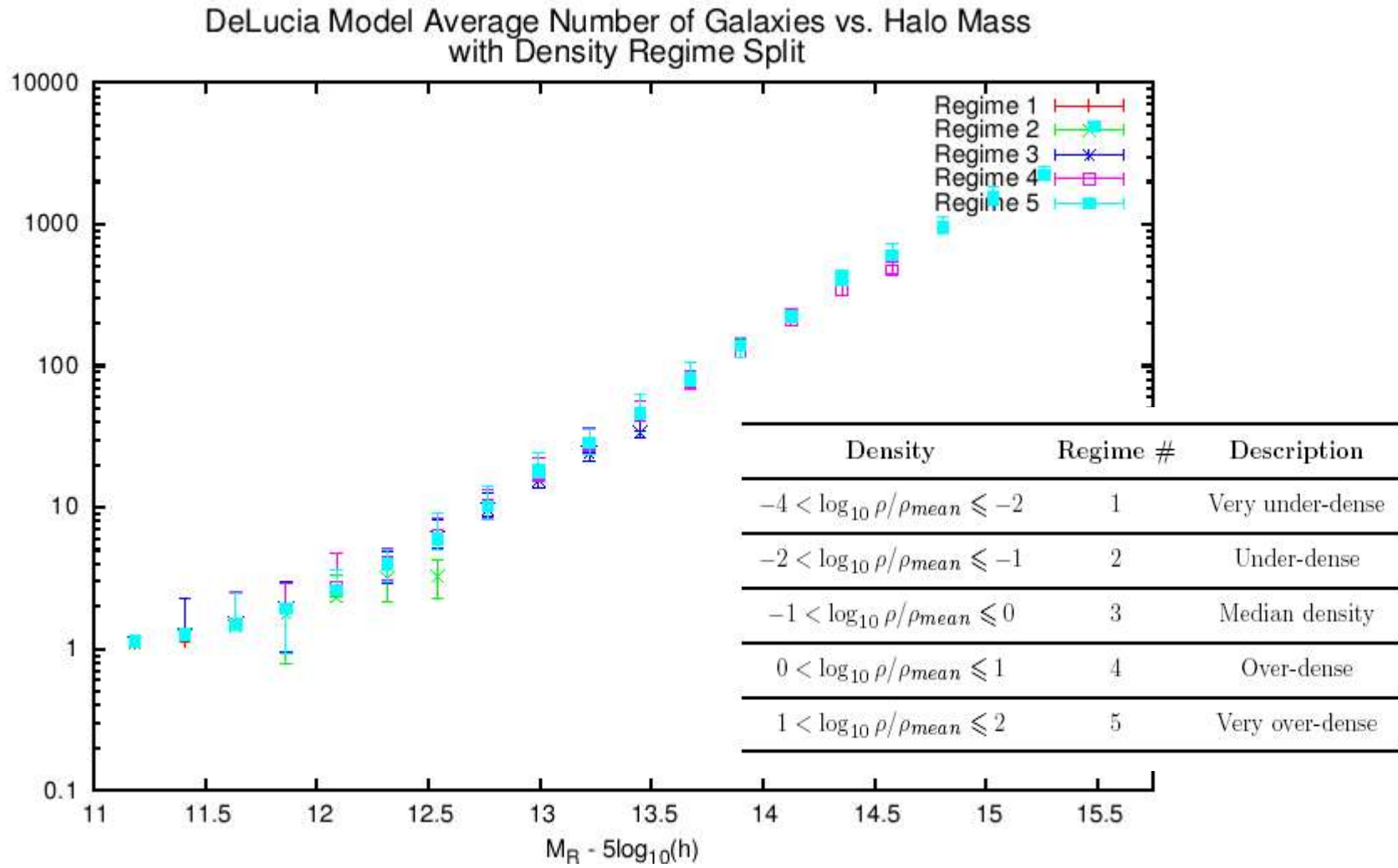
arbitrary units



DeLucia Model	85	80	75	70	65	60	55	50	45	40	35	30	25	20	15	10	5
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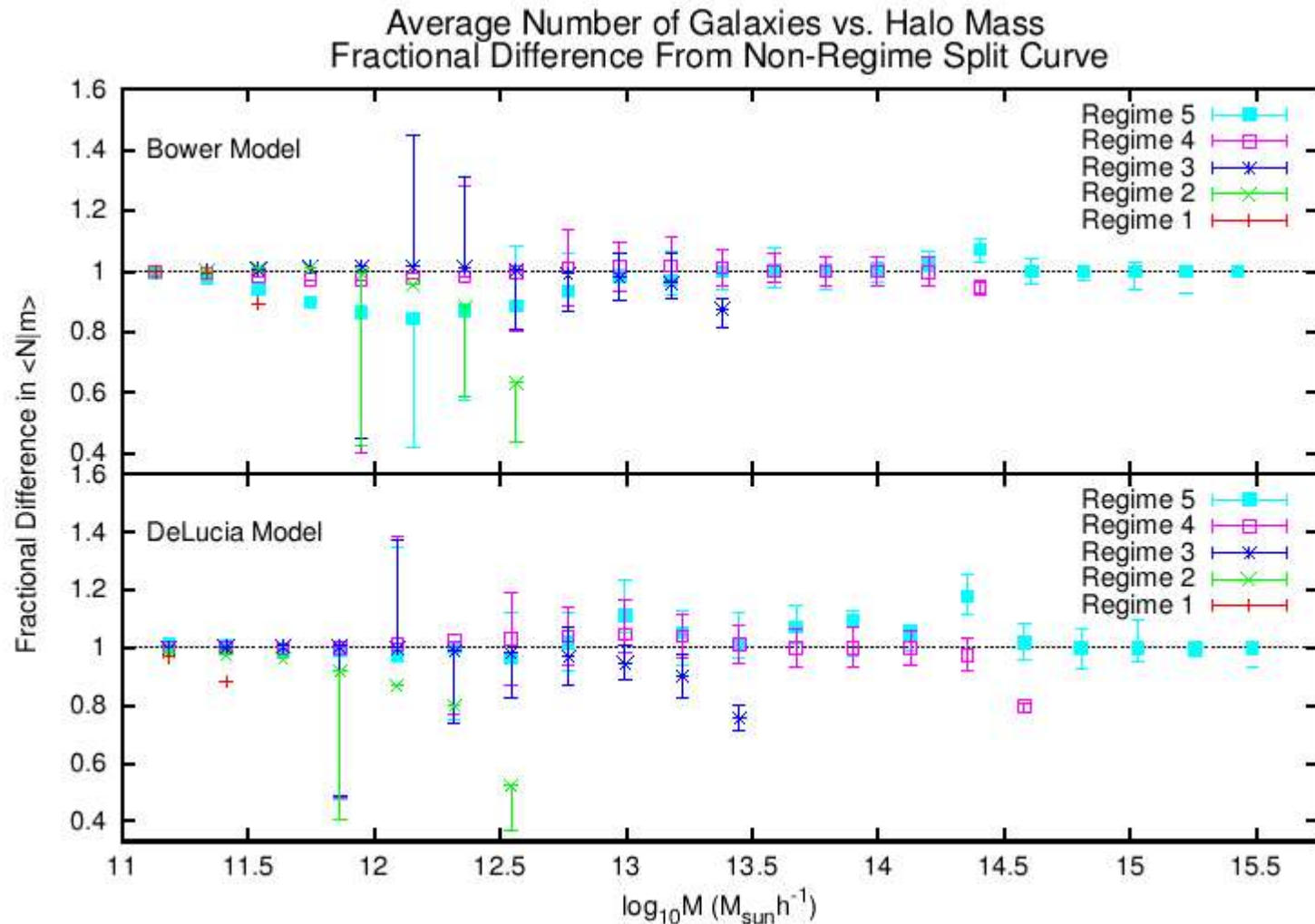
... $N(M)$ split by environment ...

Average Number of galaxies per halo



NB: the errors should be taken with a pinch of salt when effective numbers are small

... $N(M)$ split by environment ...



NB: the errors should be taken with a pinch of salt when effective numbers are small

... Preliminary conclusions ...

- both semi-analytics models are still rather well described by standard HONs.
- environment, even though important, does only marginally affect the HONs.
- Only when the very highest precision is needed (eg. BAO experiments), such environmental effects might need to be included.