Theory of Structure Formation

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Outline:

• Introduction

• Models and Tests

• Evolution of Galaxy Clustering

• Confrontation with Observations

• Conclusions and Prospects
Models for Large-Scale Structure

The observed large-scale features in the galaxy distribution, the dark matter problem, and the detection of large-scale flows are among the important observational constraints on models for the formation and evolution of the large-scale distribution of galaxies.

Fig. 5. A 360° view that shows the relationship between the “Great Wall” of Fig. 3, C and D, and the Perseus-Pisces chain of Fig. 3A. This slice covers the declination range 20° ≤ δ < 40°. It contains all of the available data in the region (6112 galaxies with v_z ≥ 15,900 km s⁻¹; the sample is not magni-
Gravitational 'Jeans' instability

static universe:

\[ \rho \geq \rho_0 \rightarrow \rho \gg \rho_0 \]

expanding universe:

\[ \rho \geq \rho_0 \rightarrow \rho \gg \rho_0 \]
early universe inflation?

- gravity
- particle physics
- dissipation
- damping
- free-streaming
- radiative effects
- pressure effects
- star formation
- heating
- non-linear effects

simulation

↓
observations
\[ \delta(x) = \sum_{k} \delta_k e^{ikx} \]

- \( P(k) \) - variance of Fourier modes \((k^n)\)
- \( P(k) \) is complete for Gaussian (random phase)
- FT of \( \delta(x) \)

**Linear Regime**

\[ P_{\text{pow}} (k, t_f) \rightarrow P_{\text{in}} (k) D^2 (r) T_p^2 (k) \]

(Fourier modes independent)

**Non-linear Regime**

- \( P(k) \) changes shape
- Phases not random
- Higher-order perturbations
- Scaling arguments
- Numerical methods (N-body)
MENU

- Background Cosmology ($\Omega_0$, $H_0$ and $\Lambda$).

- Initial Fluctuations (Origin, Statistics, Spectrum, Mode)

- Ingredients (CDM, HDM, baryons, photons...)

- Normalization (COBE)

- Engine (‘Active’ or ‘Passive’)

- Bias
CDM
(Fixed Price)

$\Omega_0 = 1$, $H_0 = 50$, $n = 0$

Inflation, Gaussian, $n = 1$, adiabatic

$\langle \rho_{\text{com}} \rangle \ll \Omega_b$

$\sigma_8$?

L.J.

$! ? b$ \( \frac{\Delta \rho_b}{\rho_b} = b \left( \frac{\rho_b}{\rho_b} \right) \)
To cut a long story short.....

QDOT + APM + ... + COBE ≠ SCDM

So there is now a ZOO of models which look like CDM with epicycles:

- OCDM ($\Omega_0 \approx 0.3$)
- TCDM ($n \neq 1$, with or without GWs)
- LCDM ($\Lambda \neq 0, k = 0$)
- CHDM (Mixed Dark Matter)
- CVDM (Volatile Dark Matter)
- ...
- CGFCDM! (Cooperative Galaxy Formation)
TESTS OF MODELS

• COSMOLOGY!
• CLUSTER ABUNDANCES \((z=0) \Rightarrow \sigma_8\)
• GALAXY POWER SPECTRUM \(P(k) (\Gamma)\)
• PECULIAR VELOCITIES
• HIGH REDSHIFT OBJECTS (QSO, Ly-\(\alpha\), CLUSTERS)
• CMB!
• HIGHER-ORDER STATISTICS

REDSHIFT EVOLUTION

? \rightarrow STRUCTURE FORMATION

COSMOLOGY

? \rightarrow ?
BIAS - THE EARLY YEARS

\[ V \iff \frac{\delta P}{P} \quad \left( \text{Virgo + C.V.T.} \right) \]

\[ \Rightarrow \Omega_0 \approx 0.2 \]

But if fluxes in mass lower than fluxes in galaxy then \(-\Omega_0 \uparrow\)

\[ \xi_{cc}(r) \approx \text{const} \xi_{gg}(r) \]

Why not \( \xi_{gg}(r) \approx \text{const} \xi_m(r) \)?

Kaiser (1984) - High - Peak
Galaxies with biasing.

From Davis, Efstathiou, Frenk + White

Ap. J 292
CDM N-BODY SIMULATION.
\[ \delta(x) \]

THEORY

\[ \downarrow \]

? 

OBSERVATION

\[ \cdots \cdots \cdots \cdots \cdots \cdots \]

POISSON CLUSTERING

\[ \sum P(x) \propto \int P(x) \delta^3 x \]

\[ \propto (1 + \delta(x)) d^3 x \]

BIASED - LOCAL e.g. \[ \sum P \propto f(\delta) d^3 x \]
\[ b^2(r) = \frac{\xi_{gg}(r)}{\xi_{mm}(r)} \quad \text{(Coles 1993)} \]

IS DECREASING FUNCTION OF R.

- ALTER LARGE-SCALE SHAPE ONLY WITH NON-LOCAL BIAS ....
  - E.G. COOPERATIVE C.F. EXPLOSIONS ... , ETC

N.B. BEWARE!

\[ \left( \frac{\xi_{gg}}{\xi_{mm}} \right)_g = b \left( \frac{\xi_{gg}}{\xi_{mm}} \right)_m \]

\[ \xi_{gg}(r) = b^2 \xi_{mm}(r) \]

\[ \sigma^2_g(r) = b^2 \sigma^2_m(r) \]

\[ p_g(k) = b^2 p_m(k) \]

THINGS COULD BE WORSE!

\[ \delta_g = f(\delta, \varepsilon) \]
NON-LINEAR EVOLUTION
- THE EASY WAY

\[ \Gamma_0 = \left[ 1 + \bar{\xi}(r, z) \right]^{1/3} \]

\[ \bar{\xi}(r, z) = \frac{3}{r^3} \int_{0}^{r} y^2 \bar{\xi}(y, z) dy \]

\[ \bar{\xi}(r, z) = F \left[ \bar{\xi}_{\text{lin}}(r, z) \right] \]

"UNIVERSAL"
Power spectrum of galaxy clustering

\[ \Delta^2(k) \equiv 4\pi k^3 P(k) \]
al. (1995). Virtually all present-day galaxies with $L \gtrsim 2.5L_*$ have such a progenitor. The fraction of Lyman-break descendants decreases with decreasing luminosity, so that virtually no present-day galaxy with $L \lesssim L_*/5$ was ever a Lyman-break galaxy of the type observed by Steidel et al. (1995).

The assembly of the Lyman-break galaxies themselves is illustrated in Figure 12, where we plot the growth of the stellar mass of selected Lyman-break galaxies with time. The stellar mass at each redshift (which may be spread among several fragments) is plotted as a fraction of the "final" stellar mass of the Lyman-break galaxy at $z = 3$ in Figure 12a. Star formation in the Lyman-break galaxies begins very early, at $z > 6$, but only $\sim 20\%-40\%$ of the stars have formed by $z = 4$. The bulk of the stars present in these Lyman-break galaxies at $z \approx 3$ were formed in the preceding few hundred million years. The total star formation rates summed over the fragments, in units of the star formation rate at $z = 3$, are plotted in Figure 12b.

The buildup of the population of galaxies with masses typical of Lyman-break galaxies is illustrated in Figure 13. Here we plot the evolution of the comoving number density...
MODELLING THE

EVOLUTION OF

GALAXY CLUSTERING

MATARRESE ET AL. (1997) MNRAS 286, 115

EVEN IF $b \geq 1$ AT $z = 0$,

IT IS LARGER AND MORE

UNCERTAIN AT HIGH $z$...
Correlation Function

\[ \delta P_{12} = \bar{n}^2 \left[ 1 + \xi(r_{12}) \right] \delta V_1 \delta V_2 \]

\[ \xi(r) = 0 : \text{"Poisson" distribution} \]
\[ \xi(r) > 0 : \text{clustered} \]
\[ \xi(r) < 0 : \text{anti-clustered} \]
$\xi_{\text{obs}}(r) = \frac{1}{N^2} \int \frac{dz_1}{2} \frac{dz_2}{2} N(z_1) N(z_2) b_{\text{eff}}(z_1) b_{\text{eff}}(z_2) \times \xi^*(r, z)$

- Assume $\delta_n = b \delta_m$, $b = b(M, z)$

\[ b_{\text{eff}} = \frac{1}{N(z)} \int d \log M' b(M', z) N(z, M') \]

Also

$\xi_{\text{obs}}(\theta) = \frac{1}{N^2} \int \frac{dz}{2} h(z) N^2(z) b_{\text{eff}}^2(z) \int \frac{du}{u} \sum [\xi(\nu, 0, z, z)]$

or

$\xi_{\text{obs}}(r_p) = 2 \int dy \xi_{\text{obs}}(\sqrt{r_p^2 + y^2})$
MODELS FOR $b(z)$

1. "unbiased" $b = 1$

2. "galaxy conserving"

$\quad b(z) = 1 + (b_e - 1) \frac{D(z)}{D_e(z)} \quad z < z_e$

\[ \downarrow \]

linear growth law

\[ M_{\text{O-White}} \]

$\quad b(M, z | z_e) = 1 + \frac{D(z)}{\frac{\delta_c^2}{\sigma_e^2} D_e(z)} \left( \frac{\delta_c^2}{\sigma_e^2} \frac{\delta_e}{\sigma_e}^2 - 1 \right) \]

\[ \downarrow \]

1.68 for flat model.

(need to introduce $M_{\text{min}}$)

3. merging model

$\quad b_{\text{eff}}(z) = 1 - \frac{1}{\delta_c} + \left[ b_{\text{eff}}(0) - 1 + \frac{1}{\delta_c} \right] \frac{1}{D(z)^2}$

4. transient model - $M_{\text{min}}$ free

$\quad b_{\text{eff}}(z) = b_{-1} + (b_0 - b_{-1}) (1+z)^3$
a telescope is a time machine
Figure 1. The effective bias $b_{\text{eff}}$ as a function of the redshift $z$ for the cosmological models considered in this paper. The different solid lines refer to different values of the minimum mass $M_{\text{min}}$ in the Press-Schechter mass-function, ranging from $10^9$ to $10^{14}$ $h^{-1} M_\odot$, from bottom to top. The dotted lines show the effects of the catalogue selection: the results are obtained by assuming a bolometric magnitude limit $m_{\text{lim}} = 24$, a mass-to-luminosity ratio $M/L = 10 M_\odot/L_\odot$ and a K+E-correction expressed by the relation $K \log(1+z)$, with $K = -1, 0, +1$ (from bottom to top).

We should make the point that these simple schemes do not exhaust all the possible scenarios through which galaxies might have formed and evolved. For example, it is quite possible that merging could play a different role at different redshifts. Present day bright disk galaxies, for example, have clearly not just formed at the present epoch since their properties suggest a lack of mergers in the recent past. On the other hand, it is plausible that galaxies at much higher redshifts, say $z \sim 2$, are undergoing merging on the same timescale as the parent haloes. This suggests the possible applicability of a model where rapid merging works at high redshift, but it ceases to dominate at lower redshifts and the bias then evolves by equation (22) until now. In this context it is interesting to note that, while $b_f$ is a free parameter in equation (22), it is actually predicted by equation (24), once the appropriate minimum mass is specified. Thus matching the merging phase (24) onto the conserving phase (22) gives...
Figure 2. The fits to the function $b_{eff}(z)$ for each cosmology discussed in this paper and for the four different biasing models described in the text: unbiased model (solid line); galaxy-conserving model (dotted line); merging model (short-dashed line); transient model (long-dashed line).

A bolometric magnitude limit of $m_{lim} = 24$, a mass-to-luminosity ratio $M/L = 10 M_\odot/L_\odot$ and a K+E-correction parametrised by the relation $K \log(1+z)$. The results for $K = -1, 0, +1$ are shown as dotted lines in Fig. 1. The general effect of this 'selection bias' is to exaggerate the increase of the bias factor with redshift even further. This is particularly evident when small minimum masses $M_{min}$ are considered, though it has little effect on the quantitative results we have obtained in the next section, and none at all on their qualitative interpretation. We shall not therefore discuss this detail any further in our analysis.

4 SIMPLE MODELS OF CLUSTERING EVOLUTION

As we mentioned in the Introduction, theoretical interpretations of information on clustering evolution have frequently been rather naive. In particular, many observational results are quoted in terms of the parameter $\epsilon$ in the following

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Figure 8. In this diagram, each wedge represents a cone of fixed opening angle, with the observer (us) at the point of the cone, at zero redshift. The wedges show the relation between physical sizes, namely the comoving distances in the radial (vertical) and transverse (horizontal) directions, and observable quantities, namely redshift and angular separation, in three different cosmological models: (left) flat matter-dominated Universe; (middle) open matter-dominated Universe with $\Omega_0 = 0.2$; (right) flat Universe with a cosmological constant, $\Omega_\Lambda = 0.8$.

9. Cosmological Redshift Distortions

The relation between redshift and radial comoving distance, and between angle and transverse comoving distance, is different for different cosmological models, as illustrated in Figure 8. The differences produce a cosmological redshift distortion that is zero at zero redshift, but that becomes more marked at higher redshift.

The idea of using cosmological redshift distortions to measure cosmological parameters, notably the cosmological constant, was first proposed by
future disturbance in open models when free expansion takes over (cf. Padmanabhan et al. 1996). The \( \Lambda \)CDM model is intermediate between these two, with clustering only freezing out much later as the expansion begins to accelerate.

The situation for the galaxies, however, is much more confused than the case for the matter. Different biasing models yield very different predicted behaviours for \( \epsilon(z) \), which suggests that the usefulness of this parametrisation of clustering is most limited for precisely those objects which one could actually observe. Notice also that the value of \( \epsilon \) depends on the scale at which it is measured, adding further confusion to its interpretation.

As well as \( \epsilon \), which measures the rate of evolution, one is also interested in what the characteristic length scale of clustering might be as a function of redshift. One way to encode this information is via the quantity \( r_0(z) \), the distance at which the correlation function has unit amplitude. This quantity represents a kind of characteristic scale of the clustering pattern, so one might try to compare the sizes of individual structures with this quantity.

In hierarchical clustering models, the generic expectation is that this (comoving) characteristic scale must decrease with increasing redshift. Fig. 4 demonstrates that, while this is certainly true for the distribution of mass, it need
not be true for galaxies selected with particular forms of bias. An $r_0$ that increases with redshift is obtained in both merging and transient models in most cases.

The fundamental point that arises from these considerations concerns the approach one adopts to test theories. In the present situation, one is attempting to eliminate some particular well-defined models from a shortlist of contenders. In other words, our aim is hypothesis testing. This kind of test is best performed in the 'observational plane', i.e. by computing exactly what an observer would see in a given model universe and comparing it with what is seen in ours. It is not useful in our view to treat the problem as one of inference, where one tries to fit a model parameter (in this case $\epsilon$) to the observations, particularly a parameter which is of such limited usefulness and theoretical significance.
the combination of biasing scheme and cosmological model. All combinations are excluded for SCDM. The merging model is always excluded in any cosmology (cf. Roukema & Yoshii 1993). The galaxy-conserving model can fit the data only within the \( \Lambda \)CDM model. The models which appear to be in best agreement with the data are the unbiased and transient bias schemes in low density models (either with or without a \( \Lambda \)-term).

5.5 CFRS Projected Correlation Function

The CFRS data have been analysed also in terms of the projected correlation function by Le Fèvre et al. (1996). They divided the galaxies in three different strips in redshift with median redshift \( z \approx 0.34, z \approx 0.62 \) and \( z \approx 0.86 \). We use these median redshifts to rescale in comoving coordinates the projected separations, originally plotted in proper coordinates. Their correlations have been computed by using \( q_0 = 0.5 \); consequently the results have to be translated...
for different models because both \( w(r_p) \) and the distance \( r \) depend on cosmology. For this goal we follow Peacock (1997), particularly his discussion of the same observational dataset in Section 4.1 of that paper and specifically using his equation (40).

The results, presented in Fig. 8, show that the transient model is compatible with the data for all cosmologies, though this is marginal in the case of SCDM. The unbiased model is compatible with the data for SCDM_{CL}, TCDM and OCDM. On the other hand, the merging and galaxy-conserving models are always inconsistent.

### 5.6 Keck K-band Projected Correlation Function

The projected correlation function has been computed also for the Hawaii Keck K-band survey by Carlberg et al. (1997). They present the results for four different redshift strips, with median redshift \( z \approx 0.34, z \approx 0.62, z \approx 0.97 \)
Figure 7. Theoretical prediction in different cosmological models for the angular galaxy correlation function for the Hubble Deep Field. The results are for the sample with magnitude limit $R = 29$ and median redshift $z_0 = 1.87$. The redshift distribution is given by equation (31). The shaded region in the plots refers to the $1\sigma$ range allowed by the fit obtained on the observational data by Villumsen, Freudling & da Costa (1997). Different bias models are shown as in Fig. 2.

and $z \approx 1.39$, by adopting $q_0 = 0.1$. As before, we rescale in comoving coordinates by using the median redshifts and we translate the observational results for different cosmological models following Peacock (1997). Notice that the observational data used here are different with respect to those used in Paper I presented in an earlier version of the Carlberg et al. paper.

Interpretation of the results, reported in Fig. 9, is slightly complicated by the strange shape of the measured correlation function at low $z$. One could resort to a scale-dependent bias to solve this difficulty (see below), but in any case this makes it difficult to exclude models on the basis of the results for the low redshift bin. It is worthwhile, however, considering what one might conclude if some of these results were subject to an unknown error. If one accepts the points at small separations as being 'accurate', then they favour the number-conserving and merging models in all the cosmologies, and also are consistent with an unbiased model for $\Lambda$CDM and SCDM. If instead one
Figure 8. Theoretical prediction in different cosmological models for the projected galaxy correlation function of the Canada-France Redshift Survey sample as a function of the (comoving) separation $r_p$ (in units of $h^{-1}$ Mpc). The redshift distribution is given by Crampton et al. (1995). Correlation data are from Le Fèvre et al. (1996). Different rows refer to different strips in redshift: $0.2 < z < 0.5$ (top), $0.5 < z < 0.75$ (centre) and $0.75 < z < 1$ (bottom). Different bias models are shown as in Fig. 2.

discards these points and concentrates on the intermediate separation points, they favour the transient and unbiased models for SCDM, TCDM and OCDM.

The data at larger redshifts have much larger errors, but it emerges robustly that the merging model is excluded by the data for any cosmology. Generally speaking the unbiased and transient model are reasonable fits in all cases considered, though for SCDM the unbiased case is only marginally acceptable. For consistency, these results at higher $z$ lead one to prefer the interpretation that the putative problem with the low-redshift data does indeed affect the small-separation points, rather than those at larger scale but this argument is, of course, not rigorous.
5.7 Lyman-Break Galaxies

Steidel et al. (1996, 1998) have reported evidence for the existence of a strong concentration of galaxies at $z \sim 3$ in their angular field. This 'spike' contains 15 objects (plus one faint QSO) in a redshift bin of width $\Delta z = 0.04$. Various authors have discussed the probability of such an object arising in particular cosmological scenarios (Mo & Fukugita 1996; Baugh et al. 1997; Steidel et al. 1998; Jing & Suto 1998; Governato et al. 1998; Bagla 1997a; Wechsler et al. 1997; Peacock et al. 1998), reaching somewhat equivocal conclusions.

Although not designed for this particular problem, which can only be resolved in an entirely satisfactory fashion using N-body simulations, the formalism we have constructed in this paper can be used to shed qualitative light on the concentration of Lyman-break galaxies in a very simple way. In principle, the correct theoretical tool to this
The redshift histogram of the 67 color-selected objects with $z > 2$ that have been confirmed spectroscopically in a 8'7 by 17'6 strip. The dotted curve represents the smoothed redshift selection function obtained to date for our overall survey, normalized so as to have the same number of total galaxies as the SSA22 sample. Approximately one-third of the confirmed redshifts are from the SSA22 fields. The binning here is arbitrary; the formal boundaries of any "features" in the redshift distribution used for analysis were obtained using the method described in §3 and in the appendix.
Figure 9. b. As Fig. 9a but for different strips in redshift: $0.8 < z < 1.2$ (top) and $1.2 < z < 1.6$ (bottom).

The purpose would be the formula for the probability of finding $N$ objects in a given volume, which for each model depends on both the mean number of objects and on all the hierarchy of correlation functions, suitably smoothed over the volume (White 1979). However, no sound theoretical predictions exist for the evolution of the entire hierarchy of correlation functions into the non-linear regime. We can, however, get a useful insight by calculating the expected number of neighbours $N_R$ within a distance $R$, given the presence of an object at the origin. This is larger than the mean number of galaxies in a randomly-selected volume by a factor of $[1 + \xi(R)]$; this factor therefore measures the average 'excess' number of galaxies that tend to accompany a given galaxy. At redshift $z$, the quantity $N_R$ is related to the integrated mass correlation function $\xi$ by $N_R = \bar{N} [1 + k_0(z) \xi(R, z)]$, where $\bar{N}$ is the mean number of objects in a sphere of radius $R$. In order to calculate this we need to know three different quantities: the value of $\bar{N}$; the radius $R$ corresponding to the volume of the considered bin; the appropriate model of bias.

The value of the mean number of objects can be taken directly from the smoothed redshift selection function, obtained by Steidel et al. (1998) from the whole survey. From their Fig. 1, it is possible to infer that $\bar{N} \sim 4.5$ at $z \sim 3$. As for the radius $R$, the volume of the bin depends on the cosmology because of the dependence of proper
Figure 10. Theoretical prediction in different cosmological models for the observed spatial correlation function of the Lyman-break galaxies as a function of the (comoving) separation $r$ (in units of $h^{-1}$ Mpc). The redshift distribution is taken from Steidel et al. (1998). A minimum mass of $10^{12} h^{-1} M_{\odot}$ is used to compute the effective bias.

chosen as before. The results obtained for a minimum mass of $10^{12} h^{-1} M_{\odot}$ (that we found to be in better agreement with the observation of the concentration of 15 galaxies at $z \sim 3$) are shown for the different cosmological models in Fig. 10. From their N-body simulations, Governato et al. (1998) found that the effect of redshift distortions is strong at (comoving) scales smaller than $\sim 1 h^{-1}$ Mpc (see also Wechsler et al. 1997). For this reason we prefer to plot our results only for larger scales. We find that the predictions for the various models are quite different, in agreement with the analysis of Wechsler et al. (1997). The correlation length $\xi_0$ (reported in Table 3) ranges from $2.7 h^{-1}$ Mpc for SCDM to $7.3 h^{-1}$ Mpc for TCDM$_{GW}$. These differences, mainly due to the large spread in the value of the bias parameter $b_M$ at high redshifts, seem to indicate that the measurement of the correlation function of these objects (when reliably available) can be used to constrain the cosmological models.
Figure 1. Theoretical prediction in different cosmological models for the angular correlation function of the Lyman-break galaxies. The adopted redshift distribution and the correlation data are taken from Giavalisco et al. (1998). Open and filled squares (with 1σ errorbars) refer to two different estimators of the angular correlation, PB and LS respectively (see Giavalisco et al. 1998 for a discussion). Two different minimum masses are used to compute the effective bias: $10^{11} h^{-1} M_\odot$ (top panel) and $10^{12} h^{-1} M_\odot$ (bottom panel).

Figure 2. Theoretical prediction in different cosmological models for the projected correlation function of the Lyman-break galaxies as a function of the (comoving) separation $r_p$ (in units of $h^{-1}$ Mpc). The redshift distribution is given by Giavalisco et al. (1998). Two different minimum masses are used to compute the effective bias: $10^{11} h^{-1} M_\odot$ (top panel) and $10^{12} h^{-1} M_\odot$ (bottom panel).

$$w_{obs}(r_p) = 2 \int_{r_p}^\infty dr \left( r^2 - r_p^2 \right)^{-1/2} \xi_{obs}(r) ,$$

where $r_p$ is the component of the pair separation perpendicular to the line of sight. Predictions for the projected correlation function are shown in Figure 2.

Notice that the order of the amplitudes of these curves for different models is different from the angular correlation function. This is because of the different weighting by redshift and the dependence on background cosmology of the formulae.

One has to be a little cautious about the interpretation of these results because of the relatively small physical scales being probed by the sky correlations observed. The formula (4) was derived using quasi-linear arguments which are not strictly valid on small length scales. In particular, one would expect that for spatial separations of order half the initial Lagrangian radius of the haloes, their correlation function should become negative due to exclusion effects (Lacey & Cole 1994; Porciani et al. 1998). This problem is not restricted to this analysis, but is endemic in studies of this kind (e.g.,

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CONCLUSIONS / PROSPECTS

GENERAL

- LSS AT z > 0 - WAIT AND SEE!
- COSMOLOGY → STRUCTURE FORMATION
- SIMPLE MODELLING (via b) IS NEAR THE END OF THE ROAD...

PARTICULAR

- IF ANY XCOM MODEL Merging and galaxy conserving are out.
- CLUSTER ABUNDANCE OR → HIGH & OK IF b=1
- DATA SEEM TO PREFER b=1 \Rightarrow \lambda_0 < 1
- LBG FAVOUR LOW \lambda_0 (IF 10^{11} h^{-1} M_\odot)