Large–Scale Angular Correlations in CDM Models

Lauro Moscardini\textsuperscript{1}, Stefano Borgani\textsuperscript{2}, Peter Coles\textsuperscript{3}, Francesco Lucchin\textsuperscript{1}, Sabino Matarrese\textsuperscript{4}, Antonio Messina\textsuperscript{5} & Manolis Plionis\textsuperscript{6}

\textsuperscript{1}Dipartimento di Astronomia, Università di Padova, vicolo dell’Osservatorio 5, I–35122 Padova, Italy

\textsuperscript{2}INFN, Sezione di Perugia, c/o Dipartimento di Fisica dell’Università, via A. Pascoli, I–06100 Perugia, Italy

\textsuperscript{3}Astronomy Unit, School of Mathematical Sciences, Queen Mary & Westfield College, Mile End Road, London, E1 4NS, UK

\textsuperscript{4}Dipartimento di Fisica G. Galilei, Università di Padova, via Marzolo 8, I–35131 Padova, Italy

\textsuperscript{5}Dipartimento di Fisica A. Righi, Università di Bologna, via Irnerio 46, I–40126 Bologna, Italy

\textsuperscript{6}SISSA – International School for Advanced Studies, via Beirut 2–4, I–34014 Trieste, Italy

The Astrophysical Journal Letters, submitted
Abstract

We investigate the behaviour of the angular (projected) galaxy–galaxy correlation function, \( w(\vartheta) \), in the framework of Cold Dark Matter (CDM) models. We compare the situation for the standard CDM model with Gaussian (i.e. random–phase) initial fluctuations with comparable CDM models with non–random phases. To do this, we have generated artificial Lick maps using \( N \)-body simulations so that we reproduce the main features of this catalog as accurately as we can. We compare the \( w(\vartheta) \) measured from the simulations with the APM correlation (scaled to the depth of the Lick map). For the Gaussian CDM model, we find that neither the standard normalisation \( (b=1.5) \) nor a more evolved model \( (b=1) \) (as suggested by the COBE data), can reproduce the correlations on large angular scales \( (\vartheta \gtrsim 2.5^\circ) \). We come to a similar conclusion about CDM models with positively skewed initial fluctuation distributions, and can therefore exclude this choice for initial non–random phases. In contrast, models with initially negatively skewed fluctuations produce a \( w(\vartheta) \) that declines much more gently on large scales. Such models are therefore, at least in principle, capable of reconciling the lack of large–scale power of the CDM spectrum with the observed clustering of APM galaxies.

Subject headings: Galaxies: formation, clustering – large-scale structure of the Universe – early Universe – dark matter.

1 Introduction

The Standard Cold Dark Matter (SCDM) model has long been the ‘standard’ model of galaxy formation and clustering because of its great success at explaining the small scale dynamics and clustering of galaxies, once these are identified with high peaks of the initial density fluctuations, in the spirit of the biased galaxy formation model (see Frenk 1991 for a review). In recent times, however, the availability of various data sets, which are sensitive to larger scale features of the galaxy distribution, has caused a re–evaluation of the status of the SCDM picture.

A variety of different observational probes of the large–scale distribution of matter in the Universe indicate that the great weakness of SCDM is that it lacks sufficient power on scales \( > 20 – 30 \, h^{-1}\text{Mpc} \) to be consistent with the real Universe. The first compelling evidence that this was the case came with the measurement of the angular two–point correlation function of galaxies identified in projection on the sky using the APM device (Maddox et al. 1990b). The great advantage of these data over previous analyses of the Lick catalog (Groth & Peebles 1977) is the careful control of systematic errors achieved by using an automated plate–scanning device (Maddox et al. 1990a, c). Indeed, an analysis of angular correlations of galaxies identified using the COSMOS machine (Heydon–Dumbleton, Collins, & MacGillivray 1989) has come to similar conclusions to those of APM (Collins, Nichol, & Lumsden 1992). Nevertheless, there
does remain some residual doubt that there may be systematic errors in the calibration of the magnitude limit on the plates scanned by these automatic machines (Fong, Hale–Sutton, & Shanks 1992). For such errors to be responsible for the excess power detected in $w(\theta)$ requires them to be correlated amongst adjacent plates and, while this is not impossible, no compelling mechanism has been suggested as to how these errors might be introduced.

Subsequent analyses of the three–dimensional clustering of IRAS galaxies in the QDOT catalog (e.g., Efstathiou et al. 1990; Saunders et al. 1991) and, more recently, of a redshift survey of APM galaxies (Loveday et al. 1992) provide independent confirmation of the projected APM & COSMOS results. Moreover, the temperature fluctuations in the Cosmic Microwave Background (CMB) detected recently by the COBE team (Smoot et al. 1992) indicate a higher fluctuation amplitude on large scales than expected in SCDM. There is also evidence for higher fluctuations in the mass distribution from galaxy peculiar motions (Bertschinger et al. 1990) and the large–scale clustering of galaxy clusters (Batuski, Melott, & Burns 1987).

Various possible remedies for this large–scale weakness have been suggested in the literature. A direct method of obtaining extra fluctuations on large scales is to introduce a dark matter component with a larger coherence length than CDM. The resulting ‘mixed dark matter’ (MDM) models, in which there is both a cold and a hot component (Valdarnini & Bonometto 1985; Achilli, Occhionero, & Scaramella 1985), seem to agree with most of the clustering observations (van Dalen & Schaefer 1992; Taylor & Rowan–Robinson 1992; Davis, Summers, & Schlegel 1992; Klypin et al. 1992). A low–density CDM model with $\Omega_0 \sim 0.2$ is also a viable possibility, especially if one adds a cosmological constant term so that the resulting model is spatially flat (Efstathiou, Sutherland, & Maddox 1990). It has been speculated that a CDM model with a lower bias might be in accord with the observations (Couchman & Carlberg 1992); more complex astrophysical effects may also induce a scale–dependent bias (Babul & White 1991; Bower et al. 1993; Coles 1993). Choosing a primordial fluctuation spectrum which is tilted away from the standard Zel’dovich scale–invariant form (Lucchin & Matarrese 1985; Salopek, Bond, & Bardeen 1989; Adams et al. 1993) is another way to introduce large–scale power, but this alternative is strongly constrained (Vittorio, Matarrese, & Lucchin 1988; Lid- dle, Lyth, & Sutherland 1992; Cen et al. 1992; Tormen et al. 1993). Another alternative is to invoke a skewed (i.e., non–Gaussian) distribution of primordial fluctuations whilst keeping the primordial scale–invariant spectrum (Moscardini et al. 1991, hereafter MMLM; Matarrese et al. 1991; Messina et al. 1992; Weinberg & Cole 1992). All these possibilities lack the compelling theoretical simplicity of the SCDM model but we must consider all of them as potentially viable until excluded by empirical data.

Given the prominence of the APM & COSMOS angular correlation functions amongst the evidence against CDM, we decided to look in detail at the behaviour of the angular correlations of galaxies in CDM models. In this Letter we shall address two main questions.

First is the question as to what extent the APM result actually rules out SCDM, or even CDM with a low bias à la Couchman & Carlberg (1992). Previous analyses of this question
have used a mixture of linear theory and the Limber equation to compare the expected angular correlation function with the observed one. Fortunately we have already extracted realistic projected galaxy catalogs from full N–body simulations with CDM power–spectrum (Coles et al. 1993b, hereafter CMPLMM; Borgani et al. 1993). We can therefore perform a much more direct evaluation of the expected correlation function from numerical simulations than is possible with the usual mixture of analytic and numerical techniques. In Section 2 below, we shall therefore use these simulations to test whether SCDM, or CDM with a lower bias, is truly at variance with the data.

The second question is whether any of the alternatives listed above are also excluded by angular correlation data. In the course of a study of the topology of the large–scale distribution of galaxies, CMPLMM generated simulated projected catalogs for CDM models with skewed initial fluctuation statistics. We shall therefore, in Section 3, take this opportunity to investigate whether skewed CDM models can be excluded by the data.

2 Standard CDM model

The first model we want to study is the SCDM model, characterized by the initial density fluctuation spectrum $P(k) \propto k^T_2(k)$, with $T(k)$ the transfer function appropriate for CDM (e.g. Davis et al. 1985). We consider a flat universe model with vanishing cosmological constant and Hubble constant $h = 0.5$ in units of 100 km sec$^{-1}$ Mpc$^{-1}$.

Our analysis is based on N–body simulations, described in detail by Messina et al. (1992) and Lucchin et al. (1993), which use a PM code with $N_p = 128^3$ particles, $N_g = 128^3$ grid–points on a cubic box of side $L = 260$ h$^{-1}$ Mpc. The ‘present time’ is fixed so that the variance of linear mass–fluctuations in a sphere of radius 8 h$^{-1}$ Mpc, $\sigma_8^2$, is unity; this normalization is consistent with the recent COBE detection of large scale CMB anisotropies (Smoot et al. 1992).

We also show results for a biased model with linear bias parameter $b = 1.5$ (i.e. we consider the same simulation, but at the time when $b \equiv \sigma_s^{-1} = 1.5$), previously referred as SCDM. With the latter normalization the slope of the galaxy spatial correlation function is best fitted by the observed value $\gamma = 1.8$. Note, however, that this normalization does not agree with the level of CMB fluctuations detected by COBE; moreover, gravitational waves do not reach a level suitable to fill the gap in this particular case (Davis et al. 1992; Liddle & Lyth 1992; Lidsey & Coles 1992; Lucchin, Matarrese, & Mollerach 1992; Salopek 1992; Souradeep & Sahni 1993).

In order to have a direct determination of the angular correlation function $w(\vartheta)$ in the simulations, we use our three–dimensional data to construct artificial catalogs in projection. As in CMPLMM, we want to mimic the Lick map. As discussed in detail in that paper, the construction of mock Lick maps requires quite a large galaxy number density, $3 \times 10^{-2} h^3$ Mpc$^{-3}$, corresponding to 530,000 galaxies in the whole simulation box. To select these galaxies in our low–resolution simulations we smooth the initial density field with a Gaussian filter of
radius $1 \, h^{-1} \, \text{Mpc}$ and pick up all particles in regions above a density threshold, fixed in such a way that the object number density equals the required value. Due to the rather simplified galaxy identification procedure, we can only assume that our selected objects roughly trace the actual galaxy distribution.

To build up our projected Lick look–a–like catalogs we then proceed as follows. Given the box–side ($260 \, h^{-1} \, \text{Mpc}$) and the solid angle we want to study ($\Omega_{II} \geq 45\,\text{deg}^2$), we need to replicate the original simulation box exploiting its periodic boundaries. In fact, although the characteristic depth of the Lick map is only $D^* \sim 210 \, h^{-1} \, \text{Mpc}$ (Groth & Peebles 1977), galaxies with much larger distances may also enter the catalog. The precise way this replication is done is described in CMPLMM: it requires three levels of replicated boxes for an overall number of 56 ones. We then assign to each of the $\sim 530,000$ galaxies an absolute magnitude according to the Schechter (1976) luminosity function, $\Phi(M) \sim \text{dex}[\alpha + 1] \times \exp[-\text{dex} \, 0.4(M^* - M)]$, with $\alpha = -1.26$, $M^* = -19.6$, truncated at both faint and bright ends so that $dN/dM = 0$ for $M > M^* + 3$ and $M < M^* - 2$; next, we determine the apparent magnitude, corresponding to its distance, taking also into account $K$–corrections and expansion effects. Finally, we select galaxies with the same magnitude limit as in the Lick map ($m_{\text{lim}} \leq 18.8$). CMPLMM verified the robustness of the results to variations of the luminosity function and contamination due to replication of the original box. The resulting projected galaxy distribution is then binned in $10 \times 10 \, \text{arcmin}$ cells, in the same way as provided by the Lick catalog.

In order to evaluate the angular two–point correlation function, $w(\vartheta)$, we use the estimator

$$w(\vartheta) = \frac{(n_i n_j)_{\vartheta}}{(\frac{1}{2}(n_i + n_j))^2_{\vartheta}} - 1.$$  \hspace{1cm} (1)

In eq.(1), $n_i$ and $n_j$ are the galaxy counts in the $i$–th and $j$–th cell, respectively, placed at separation $\vartheta$; $\langle \cdot \rangle_{\vartheta}$ indicates an average taken over all cell pairs with separation $\vartheta$. Due to the huge number of cells, which makes the $w(\vartheta)$ computation numerically expensive, we prefer to adopt two different procedures at small and large angular scales. For $\vartheta \leq 2^\circ$ we collect $10 \times 10 \, \text{arcmin}$ cells in $6^\circ \times 6^\circ$ plates. Then, the correlation function is evaluated within each of these plates and the results are averaged to give the final $w(\vartheta)$. At larger scales the smaller cells are grouped to form counts in $1^\circ \times 1^\circ$ cells, and $w(\vartheta)$ is evaluated according to eq.(1), with $n_i$ and $n_j$ provided by the counts in such larger cells. The reliability of our method is confirmed by the smooth shape of $w(\vartheta)$ around $\vartheta \approx 2^\circ$. The results of the analysis for the Gaussian CDM models are shown in Figure 1. We also plot the APM data about $w(\vartheta)$, scaled to the depth of the Lick map, as described by Maddox et al. (1990b).

The lack of power on scales larger than $\vartheta \approx 2.5^\circ$ of the SCDM model (with $b = 1.5$) is clearly evident in Figure 1; the same is also true for the more evolved ($b = 1$) model. A low–bias ($b \leq 1$) model has been advocated by Couchman & Carlberg (1992) in order to alleviate the problems of CDM at scales $\sim 20 - 40 \, h^{-1}\,\text{Mpc}$. These authors claim that a more evolved CDM distribution than the standard normalisation would give a galaxy distribution consistent
with the APM data. On the contrary, we find that the only effect of further evolving the CDM spectrum is that of increasing the small–scale correlation amplitude, while leaving the large–scale tail substantially unchanged. It is clear that a more detailed comparison between our results and that of Couchman & Carlberg (1992) would be difficult to realize. In fact, their method to estimate the angular function is rather indirect and based on projecting, via the Limber equation, the correlation data extracted from the three–dimensional simulation box. Instead, in our analysis we tried to reproduce as accurately as we can the observational setup relevant for the Lick catalog; assign luminosities to galaxies, project them in an observational cone, define a magnitude–limited sample and perform the analysis directly on the angular distribution. Although the method of identifying galaxies in our simulations is also different, we do not expect this to play an important role in determining the results.

3 Skewed CDM models

An interesting alternative to the SCDM model is provided by the possibility that primordial perturbations had non–random phases. These could result either from suitable inflationary models or in more specific models based on phase transitions in the early universe. CDM models with non–Gaussian initial conditions have been considered by MMLM (see also Matarrese et al. 1991; Messina et al. 1992), who have shown that both the clustering dynamics and the present large–scale structure of the universe are strongly affected by the sign of the primordial skewness of mass fluctuations. Models with a positive skewness rapidly cluster to a lumpy structure with small coherence length, while negative skewness models build up a cellular structure by the slow process of merging of shells around primordial underdense regions, with larger coherence length. Among these non–Gaussian models the skew–negative ones appear more successful at reproducing the observed properties of the large–scale structure in the framework of CDM models. Similar results are also obtained by Weinberg & Cole (1992), who start from scale–free skewed non–Gaussian models. CMPLMM have analyzed the two–dimensional topology and found that both Gaussian and skew–positive models do not fit observations, while skew–negative ones provides a much better agreement. Similar results have also been found by Borgani et al. (1993), who selected cluster samples from simulated Lick maps. After applying a list of statistical tests to the resulting cluster distributions, they found that several clustering features crucially depend on the initial amount of phase correlation. Coles et al. (1993a) have shown that skew–negative CDM models are much better at accounting for the observed skewness in the distribution of QDOT galaxies.

The non–Gaussian CDM models we consider are the same analyzed by MMLM, namely Lognormal (LN) and Chi–squared with one degree of freedom ($\chi^2$), chosen as distributions for the peculiar gravitational potential, $\Phi$, before the action of the CDM transfer function. Each non–Gaussian distribution actually splits in two models: the positive ($LN_p$ and $\chi^2_p$) and
negative \((LN_n\) and \(\chi^2_n\)) ones, according to the sign of the skewness for linear mass–fluctuations. Skew–positive/negative models are characterized by a primordial excess of over/under–dense regions, which is at the origin of their dynamical behaviour. Initial conditions are assigned in terms of the peculiar gravitational potential. This can be obtained in Fourier space as \(\tilde{\Phi}(k) = T(k) F(k) \tilde{\varphi}(k)\), where \(\varphi\) is a non–Gaussian random field, related to a standard Gaussian one \(w\), with flicker–noise spectrum, by a local, non–linear map: \(\varphi(x) \propto e^{w(x)}\) for \(LN\) and \(\varphi(x) \propto w^2(x)\) for \(\chi^2\). A smooth correction factor \(F(k)\) is also applied so that all our models start with exactly the standard CDM power–spectrum.

Projected maps are obtained according to the procedure described above. In Figure 2 the angular correlation function \(w(\vartheta)\) is shown both for skew–positive and skew–negative models at the time when \(b = 1\). As for the skew–positive models, there are no appreciable differences with respect to the Gaussian case. This is quite easy to understand, since for these models the effect of the initial non–random phases is to add coherence at small scales, where subsequent non–linear gravitational evolution re–arranges the clustering.

Much more interesting is the behaviour of skew–negative models. The large–scale coherence they introduce has the effect of substantially increasing the correlation amplitude at \(\vartheta \gtrsim 2^\circ\). From the right panel in Figure 2 it is evident that the \(LN_n\) model gives rise to an exceeding amount of large–scale power, which agrees with the presence of huge coherent structures generated by this model even after projection (see Figure 2 of CMPLMM). On the other hand, the \(\chi^2_n\) model produces a rather adequate large–scale correlation, although the \(w(\vartheta)\) slope is still slightly flatter than observed. However, in this paper we are not searching for a best–fit non–Gaussian model. Instead, we are investigating the effect of introducing phase correlations in the initial conditions. In this spirit, Figure 2 suggests that a skew–negative model with a rather limited non–Gaussian behavior (such as the \(\chi^2_n\) model) succeeds at accounting for the large–scale power displayed by the APM data, even within the CDM scenario.

A further question concerns whether changing the definition of present time in the simulations leads to substantially different results. To answer this, we also decided to identify the present when the slope of the spatial two–point correlation function for galaxies matches the observed one. This epoch corresponds to \(b \approx 2\) for the skew–positive models and \(b \approx 0.5\) for the skew–negative ones. The results for these cases are not reported here, since in both cases \(w(\vartheta)\) corresponds to a worse fit: skew–positive models, being less evolved, have less power on all scales; skew–negative ones, being more evolved, have exceedingly high power.

4 Conclusions

We have obtained two important results in this paper which allow us to answer the two questions we posed in the introduction.

First, and contrary to the suggestion of Couchman & Carlberg (1992), we find that CDM
models with Gaussian initial perturbations cannot reproduce the APM correlation function, even with a higher normalisation than the standard scenario.

Second, and consistent with results we have obtained in other papers, we have demonstrated that it is possible to reconcile the CDM hypothesis with observations of galaxy clustering and CMB temperature anisotropies (pointing toward a low–bias, \( b \simeq 1 \), choice) by introducing non–Gaussian primordial fluctuations.

We have found the form of \( w(\vartheta) \) to be very sensitive to the presence of initial phase correlations. In particular, models with positive skewness look rather similar to the Gaussian ones; they introduce phase correlations only at small scales, where non–linear gravitational evolution subsequently re–arrange the clustering, while leaving unchanged the large–scale pattern. The skew–negative models we have looked at generate lots of power on large scales; we can even exclude one of these models, \( LN_n \), because it produces too high a clustering amplitude on large scales. The model that fits the APM correlation function best is the \( \chi^2_n \) model which generates a reasonable amount of power on large angular scales, even with \( b = 1 \).

The reason for the success of the skew–negative models compared to the Gaussian case is the qualitatively different way in which perturbations grow. Hierarchical clustering still acts on small scales, as in the Gaussian CDM model, but large–scale structure grows by the slow merging of shells around primordial underdensities to produce a distribution with a very large coherence length. In this sense the behaviour of these models resembles that of MDM ones, where small– and large–scale structures originate in a different way.

Since we have covered only an infinitesimal part of the space of all skew–negative models, it is not surprising that we have not found one that fits the data exactly, but we have shown that, at least qualitatively, such models can explain the clustering data without too much difficulty.

Of course, we are not suggesting the \( \chi^2_n \) as a physically motivated model to fit to the observations. What we have done is demonstrate that the APM data are not in contradiction with CDM per se, merely with CDM plus the assumption of primordial random phases. A CDM model with negatively skewed primordial statistics is at least as successful as any other model at explaining galaxy clustering data. We should take non–Gaussian models seriously until they are definitely excluded by the data.
Acknowledgments

We are all very grateful to Steve Maddox for providing us with the APM correlation function in digital form. SB wishes to acknowledge SISSA in Trieste for the hospitality during several phases of preparation of this work. PC thanks the Dipartimento di Astronomia at the Università di Padova for the hospitality during a visit when some of this work was done. He also acknowledges support from SERC under the QMW rolling grant GR/H09454. This work has been partially supported by Ministero dell’Università e della Ricerca Scientifica e Tecnologica and by Consiglio Nazionale delle Ricerche (Progetto Finalizzato: Sistemi Informatici e Calcolo Parallelo). The staff and the management of the CINECA Computer Center (Bologna) are warmly acknowledged for their assistance and for allowing the use of computational facilities.
References

Achilli, S., Occhionero, F., & Scaramella, R. 1992, ApJ, 299, 577
Adams, F.C., Bond, J.R., Freese, K., Frieman, J.A., & Olinto, A.V. 1993, Phys. Rev., D47, 426
Babul, A., & White, S.D.M. 1991, MNRAS, 253, 31P
Batuski, D.J., Melott, A.L., & Burns, J.O. 1987, ApJ, 322, 48
Bertschinger, E., Dekel, A., Faber, S.M., Dressler, A., & Burstein, D. 1990, ApJ, 364, 370
Borgani, S., Coles, P., Moscardini, L., & Plionis, M. 1993, preprint
Bower, R.G., Coles P., Frenk C.S., & White, S.D.M. 1993, ApJ, in press
Cen, R., Gnedin, N.Y., Kofman, L.A., & Ostriker, J.P. 1992, ApJ, 399, L11
Coles, P. 1993, MNRAS, in press
Coles, P., Moscardini, L., Lucchin, F., Matarrese, S., & Messina, A. 1993a, MNRAS, submitted
Coles, P., Moscardini, L., Plionis, M., Lucchin, F., Matarrese, S., & Messina, A. 1993b, MNRAS, 260, 572 (CMPLMM)
Collins, C.A., Nichol, R.C., & Lumsden, S.L. 1992, MNRAS, 254, 295
Couchman, H.M.P., & Carlberg, R.G. 1992, ApJ, 389, 453
Davis, M., Efstathiou, G., Frenk, C.S., & White, S.D.M. 1985, ApJ, 292, 371
Davis, M., Summers, F.J., & Schlegel, D. 1992, Nature, 359, 393
Davis, R.L., Hodges, H.M., Smoot, G.F., Steinhardt, P.J., & Turner, M.S. 1992, Phys. Rev. Lett., 69, 1856
Efstathiou, G., Kaiser, N., Saunders, W., Lawrence, A., Rowan–Robinson, M., Ellis, R.S., & Frenk, C.S. 1990, MNRAS, 247, 10P
Efstathiou, G., Sutherland, W.J., & Maddox, S.J. 1990, Nature, 348, 705
Fong, R., Hale–Sutton, D., & Shanks, T. 1992, MNRAS, 257, 650
Frenk, C.S. 1991, in ‘Nobel Symposium No 79: The birth and early evolution of our Universe’, Physica Scripta, T36, 70
Groth, E.J., & Peebles, P.J.E. 1977, ApJ, 217, 385
Heydon–Dumbleton, N.H., Collins, C.A., & MacGillivray, H.T. 1989, MNRAS, 238, 379
Klypin, A., Holtzman, J., Primack, J., & Regős, E. 1992, preprint
Liddle, A.R., & Lyth, D.H. 1992, Phys. Lett., B291, 391
Liddle, A.R., Lyth, D.H., & Sutherland, W. 1992, Phys. Lett., B279, 244
Lidsey, J.E., & Coles, P. 1992, MNRAS, 258, 57P
Loveday, J., Efstathiou, G., Peterson, B.A., & Maddox, S.J. 1992, ApJ, 400, L43
Lucchin, F., & Matarrese, S. 1985, Phys. Rev., D32, 1316
Lucchin, F., Matarrese, S., Messina, A., & Moscardini, L. 1993, in Proc. of the International School of Physics ‘E. Fermi’ on ‘Galaxy Formation’, eds. J. Silk and N. Vittorio, in press
Lucchin, F., Matarrese, S., & Mollerach, S. 1992, ApJ, 401, L49
Maddox, S.J., Efstathiou, G., & Sutherland, W.J. 1990a, MNRAS, 246, 433
Maddox, S.J., Efstathiou, G., Sutherland, W.J., & Loveday, J. 1990b, MNRAS, 242, 43P
Maddox, S.J., Sutherland, W.J., Efstathiou, G., & Loveday, J. 1990c, MNRAS, 243, 692
Matarrese, S., Lucchin, F., Messina, A., & Moscardini, L. 1991, MNRAS, 252, 35
Messina, A., Lucchin, F., Matarrese, S., & Moscardini, L. 1992, Astroparticle Phys., 1, 99
Moscardini, L., Matarrese, S., Lucchin, F., & Messina, A. 1991, MNRAS, 248, 424 (MMLM)
Salopek, D.S. 1992, Phys. Rev. Lett., 69, 3602
Salopek, D.S., Bond, J.R., & Bardeen, J.M. 1989, Phys. Rev., D40, 1753
Saunders, W., et al. 1991, Nature, 349, 32
Schechter, P. 1976, ApJ, 203, 297
Smoot, G.F., et al. 1992, ApJ, 396, L1
Souradeep, T., & Sahni, V. 1993, MNRAS, in press
Taylor, A.N., & Rowan–Robinson, M. 1992, Nature, 359, 396
Tormen, G., Moscardini, L., Lucchin, F., & Matarrese, S. 1993, ApJ, in press
Valdarnini, R., & Bonometto, S.A. 1985, A&A, 146, 235
van Dalen, A., & Schaefer, R.K. 1992, ApJ, 398, 33
Vittorio, N., Matarrese, S., & Lucchin, F. 1988, ApJ, 328, 69
Weinberg, D.H., & Cole, S. 1992, MNRAS, 259, 652
Figure captions

Figure 1. The angular two–point correlation function, $w(\vartheta)$, for the Gaussian CDM model at two evolutionary stages: $b = 1.5$ (left panel) and $b = 1$ (right panel). Open squares and dashed lines are for the simulated Lick maps, while filled dots are for the APM correlation, as provided by Maddox et al. (1990b). It is apparent the lack of correlation at $\vartheta \gtrsim 2.5^\circ$, which is not alleviated by leaving the clustering evolving up to $b = 1$.

Figure 2. The same as in Figure 1, but for skewed CDM models, with both positive (left panel) and negative (right panel) skewness. Only the epoch associated to $b = 1$ is considered. Open squares are for the $\chi^2$ models, while open triangles are for the Lognormal models. No significant differences with respect to the Gaussian case appears for the skew–positive models. Negative skewness introduces large–scale coherence, which, for the LN model, gives an even exceeding clustering at large separations. Instead, a rather adequate shape for $w(\vartheta)$ is produced by the $\chi^2_n$ model.