The Durham/UKST Galaxy Redshift Survey – VI. Power spectrum analysis of clustering

F. Hoyle, C. M. Baugh, T. Shanks and A. Ratcliffe
Department of Physics, Science Laboratories, South Road, Durham DH1 3LE

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Abstract

We present the power spectrum analysis of clustering in the Durham/UKST Galaxy Redshift Survey. The Survey covers 1450 square degrees and consists of 2501 galaxy redshifts. The galaxies are sampled at a rate of one in three down to a magnitude limit of $b_J \sim 17$ from cosmos scanned UK Schmidt Telescope plates. Our measurement of the power spectrum is robust for wavenumbers in the range $0.04 h^{-1} \text{Mpc} < k < 0.6 h^{-1} \text{Mpc}$. The slope of the power spectrum for $k > 0.1 h^{-1} \text{Mpc}$ is close to $k^{-2}$. The fluctuations in the galaxy distribution can be expressed as the rms variance in the number of galaxies in spheres of radius $8 h^{-1} \text{Mpc}$ as $\sigma_8 = 1.01 \pm 0.17$. We find remarkably good agreement between the power spectrum measured for the Durham/UKST Survey and those obtained from other optical studies on scales up to $\lambda = 2\pi/k \sim 80 h^{-1} \text{Mpc}$. On scales larger than this we find good agreement with the power measured from the Stromlo–APM Survey, but find more power than estimated from the Las Campanas Redshift Survey. The Durham/UKST Survey power spectrum has a higher amplitude than the power spectrum of IRAS galaxies on large scales, implying a relative bias between optically and infrared selected samples of $b_{rel} = 1.3$. We apply a simple model for the distortion of the pattern of clustering caused by the peculiar motions of galaxies to the APM Galaxy Survey power spectrum, which is free from such effects, and find a shape and amplitude that are in very good agreement with the power spectrum of the Durham/UKST Survey. This implies $\beta = \Omega^{0.6}/b = 0.60 \pm 0.35$, where $b$ is the bias between fluctuations in the galaxy and mass distributions, and also suggests a one-dimensional velocity dispersion of $\sigma = 320 \pm 140 \text{km s}^{-1}$. We compare the Durham/UKST power spectrum with cold dark matter (CDM) models of structure formation, including the effects of nonlinear growth of the density fluctuations and redshift-space distortions on the theoretical power spectra. We find that for any choice of normalization, the standard CDM model has a shape that cannot be reconciled with the Durham/UKST Survey power spectrum, unless either unacceptably high values of the one-dimensional velocity dispersion are adopted or the assumption that bias is constant is invalid on scales greater than $20 h^{-1} \text{Mpc}$. Over the range of wavenumbers for which we have a robust measurement of the power spectrum, we find the best agreement is obtained for a critical-density CDM model in which the shape of the power spectrum is modified.

Key words: surveys – galaxies: clusters: general – galaxies: distances and redshifts – cosmology: observations – cosmology: theory – large-scale structure of Universe.

1 Introduction

Measuring the primordial power spectrum of density fluctuations in the Universe is of fundamental importance in the development of a model for the formation of large-scale structure. The shape and amplitude of the power spectrum contain information about the nature of dark matter and the relative densities of dark matter and baryons. Several obstacles prevent a direct measurement of the primordial power spectrum from surveys of the local Universe. The gravitational amplification of density fluctuations leads to a coupling of perturbations on different length-scales. This results in a change in the shape of the power spectrum, except on large scales where the rms fluctuations are still less than unity (e.g. Peacock & Dodds 1994; Baugh & Efstathiou 1994b). Structures...
are mapped out by galaxies and these may be biased tracers of the underlying mass distribution (Davis et al. 1985). Furthermore, the relation between fluctuations in the galaxy and mass distributions could be a function of scale and this needs to be addressed with a model for galaxy formation (e.g. Benson et al. 1999). The pattern of clustering is also distorted when galaxy positions are inferred directly from their redshifts. This is due to a contribution to the observed redshift from the peculiar motion of the galaxy that arises from inhomogeneities in the local gravitational field, in addition to the contribution from the Hubble flow (Kaiser 1987; Peacock & Doods 1994).

Measurements of galaxy clustering have improved dramatically in the last ten years with the completion of several large galaxy surveys. The infrared selected QDOT redshift survey (Efstathiou et al. 1990a; Saunders et al. 1991) and the optical, angular APM Survey (Maddox et al. 1990) were the first to demonstrate that there was more power in the galaxy distribution on large scales than expected from the standard cold dark matter (CDM) theory of structure formation. This led to variants of the standard CDM picture being considered.

The power spectrum has become the favoured statistic for quantifying galaxy clustering. This is despite the development of improved estimators for the two-point correlation function (Hamilton 1993; Landy & Szalay 1993). Both statistics are affected by uncertainties in the mean density of galaxies; however, these uncertainties affect the correlation function on all scales, whereas they only affect the power spectrum on large scales. The power spectrum is also the quantity directly predicted by theory. Errors in the power spectrum are essentially uncorrelated, before the mixing of different Fourier modes due to the convolution of the power spectrum of galaxy clustering with the power spectrum of the survey window function. Power spectra are usually estimated by a fast Fourier transform (FFT) and are therefore relatively quick to compute. Recent theoretical work (Tegmark et al. 1998) has demonstrated that power spectrum analysis can be extended to adjust for various systematic effects and biases in the data, such as obscuration by dust or the integral constraint, which we discuss in Section 4. However, in general these corrections require an assumption about the form of the underlying power spectrum and are therefore model dependent. For this reason, and because the more advanced analysis outlined by Tegmark et al. (1998) has yet to be applied to any existing galaxy survey to enable a comparison, we follow the approach developed by Feldman, Kaiser & Peacock (1994) and Tadros & Efstathiou (1996).

We apply power spectrum analysis to the Durham/UKST galaxy redshift survey. The clustering of galaxies in this survey has been studied using the two point correlation function in earlier papers of this series (Ratcliffe et al. 1996, 1998a,c,d; see also Ratcliffe 1996). Here, we restrict ourselves to a summary of the properties of the survey that are most pertinent to a power spectrum analysis of galaxy clustering.

In Section 2, we describe the Durham/UKST Survey. We outline the construction of different subsamples of the Survey for power spectrum analysis in Section 3. Power spectrum estimators are tested using mock catalogues drawn from a large numerical simulation of clustering in Section 4, we present our results in Section 5 and compare them with other surveys in Section 6. The implications for models of large-scale structure formation in the Universe are discussed in Section 7 and our conclusions are given in Section 8.

2 THE DURHAM/UKST SURVEY

Full details of the construction of the Durham/UKST Survey, including the tests made of the accuracy of the measured redshifts and of the galaxy photometry can be found in the earlier papers of this series (Ratcliffe et al. 1996, 1998a,b,c,d; see also Ratcliffe 1996). Here, we restrict ourselves to a summary of the properties of the survey that are most pertinent to a power spectrum analysis of galaxy clustering.

Figure 1. The four panels (a–d) show the galaxies in the Durham/UKST Survey. The four panels (e–h) show galaxies in the Stromlo–APM Survey which lie on the same plates. The declination slices are 5° thick and are centred on the declination shown in each panel.
The Durham/UKST Survey consists of 2501 galaxy redshifts measured with the FLAIR fibre optic system (Parker & Watson 1995). The galaxies are sampled at a rate of 1 in 3 down to a magnitude limit of $h_0 \sim 17$ from the parent Edinburgh–Durham Southern Galaxy Catalogue (EDSGC; Collins, Heydon-Dudleston & MacGillivray 1988; Collins, Nichol & Lumsden 1992). The EDSGC consists of 60 contiguous UK-Schmidt-Telescope (UKST) plates in four declination slices, covering a solid angle of $\sim 1450$ square degrees.

In Fig. 1, we contrast the visual appearance of the Durham/UKST Survey (a–d) with that of Stromlo–APM Survey galaxies (e–h) that lie on the same UK-Schmidt plates (Loveday et al. 1996). Structures in the Durham/UKST Survey are more clearly easy to pick out by eye, due to the three times higher sampling rate compared with that of the Stromlo–APM Survey. In the slices centred on $\delta = -30^\circ$, $-35^\circ$ and $-40^\circ$, the Sculptor void is visible out to $60 h^{-1}$ Mpc. (Note that we define Hubble’s constant as $H_0 = 100 h$ km s$^{-1}$ Mpc$^{-1}$.) The roof of this feature is seen in the $\delta = -25^\circ$ slice.

The radial number density of galaxies in the EDSGC is shown by the solid curve in Fig. 2, which we have computed using the luminosity function parameters given by Ratcliffe et al. (1998b). The observed radial number density of galaxies, in bins of $\Delta r = 10 h^{-1}$ Mpc, is shown by the dashed curve for the Durham/UKST Survey and by the dotted curve for the Stromlo–APM Survey. The amplitude of the Durham/UKST dashed curve lies a factor of three below the solid curve owing to the sampling rate used. The Stromlo–APM dotted curve lies approximately a factor of 20 below the solid curve owing to the sampling rate used. The Durham/UKST survey is brighter than the Stromlo–APM Survey and by the dotted curve for the Stromlo–APM Survey, the amplitude of the Durham/UKST dashed curve lies a factor of three below the solid curve owing to the sampling rate used. The Stromlo–APM dotted curve lies approximately a factor of 20 below the solid curve because the two surveys have slightly different Schechter function parameters and magnitude limits.

Figure 2. The solid curve shows the radial number density of galaxies to a magnitude limit of $h_0 \sim 17$, computed using the luminosity function of Ratcliffe et al. (1998b). The dashed curve shows the observed number density of Durham/UKST galaxies, which are sampled at a rate of one in three from the EDSGC catalogue to this magnitude limit. The dotted curve shows the radial number density of galaxies in the Stromlo–APM Survey, which are sampled at a rate of one in 20 from the APM catalogue to approximately the same magnitude limit.

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3 POWER SPECTRUM ANALYSIS

3.1 Sample definition

We use two types of galaxy sample in our power spectrum analysis of the Durham/UKST survey: (i) flux-limited and (ii) volume-limited. In order to estimate the power spectrum of galaxy clustering in these samples, we also need to construct sets of unclustered points with the same radial and angular selection; this process is described in Section 3.2.

3.1.1 Flux-limited sample

In this case, all galaxies with measured redshifts are used. A weight is assigned to each galaxy, to take into account the radial selection function of the survey. We adopt the form of the weight proposed by Feldman et al. (1994), which minimizes the variance in the estimate of the power spectrum:

$$w(r_i) = \frac{1}{1 + n(r_i)P(k)}.$$  (1)

Here $n(r_i)$ is the mean galaxy density at the position of the $i$th galaxy. This is calculated by integrating over the luminosity function of the survey, taking into account the sampling rate. There is a slight difference in the magnitude limit of each Schmidt plate in the UKST Survey (see fig. 1 of Ratcliffe et al. 1998c), so a separate radial weight function is computed for each plate. Ideally, one should use the true power spectrum in the weight given by equation (1). However, the results are fairly insensitive to the exact choice of power spectrum. Following the approach taken by Feldman et al. (1994) and by Tadros & Efstathiou (1996), we adopt a range of constant values of $P(k)$ that are representative of the amplitude of the power spectrum over the wavenumbers of interest. We define the depth of the sample as the distance for which the radial weight function $w(r) = 0.5$. For our choices of constant power in equation (1), this gives depths in the range 200–320 $h^{-1}$ Mpc. The power spectrum analysis of the flux limited catalogue therefore probes volumes in the range $1.2–4.9 \times 10^6 h^{-3}$ Mpc$^3$.

3.1.2 Volume-limited samples

The galaxies in a volume-limited sample are brighter than the apparent magnitude limit of the survey when placed at any redshift up to that used to set the volume limit, $z < z_{\text{max}}$. Hence, as well as requiring that a galaxy have a redshift $z < z_{\text{max}}$, the absolute magnitude of the galaxy must be brighter than $M_{\text{crit}} = m_{\text{lim}} - 25 - 5 \log_{10}[d(z_{\text{max}})/h^{-1} \text{Mpc}] - k(z_{\text{max}}),$  (2)

where $m_{\text{lim}}$ is the magnitude limit of the survey and we use the $k$-correction given by Ratcliffe et al. (1998b) and set $h = 1$. Again, the different plate magnitude limits are taken into account, so for a given redshift limit $z_{\text{max}}$, the critical absolute magnitude varies slightly from plate to plate. We compute the luminosity distance $d_l$ assuming an $\Omega_0 = 1$ cosmology, although our results are insensitive to this choice owing to the relatively low redshift of Durham/UKST galaxies.

In the Durham/UKST Survey, the number of galaxies in a volume-limited subset peaks at a redshift of $z_{\text{max}} = 0.06$ (Fig. 3). There are 522 galaxies in this sample. There is a slightly smaller peak for a sample limited at $z_{\text{max}} = 0.04$. This feature is particularly strong on the plate centred on $\delta = -35^\circ$. The same
peaks are also seen in volume-limited subsamples of the Stromlo–APM Survey when attention is restricted to those galaxies that lie on the Schmidt plates covered by the Durham/UKST Survey. The dotted curves in Fig. 3 are theoretical curves calculated by integrating over the luminosity function. The volume-limited samples that we consider have maximum depths in the range 120\(\pm\)230 samples that we consider have maximum depths in the range integrating over the luminosity function, and which lie on the same Schmidt plates. The number of galaxies in both cases peaks for a sample limited at \(z_{\text{max}} = 0.06\) – there is also a strong feature that can be seen in the two catalogues around \(z_{\text{max}} = 0.04\). The dotted curves show the expected number of galaxies obtained by integrating over the luminosity function, taking into account the different sampling rates of the two surveys.

Figure 3. The number of galaxies in volume-limited samples as a function of the redshift used to define the volume limit, \(z_{\text{max}}\). The solid curve shows the number of galaxies in volume-limited samples drawn from the Durham/UKST Survey. The dashed curve shows the number of galaxies from the Stromlo–APM Survey that satisfy the volume-limit constraints, and which lie on the same Schmidt plates. The number of galaxies in both cases peaks for a sample limited at \(z_{\text{max}} = 0.06\) – there is also a strong feature that can be seen in the two catalogues around \(z_{\text{max}} = 0.04\). The dotted curves show the expected number of galaxies obtained by integrating over the luminosity function, taking into account the different sampling rates of the two surveys.

3.2 Survey geometry and radial selection function

The power spectrum measured directly from a galaxy survey is a convolution of the true power spectrum of galaxy clustering with the power spectrum of the survey window function. This is because the Fourier modes are orthogonal within an infinite or periodic volume, rather than the complicated geometry probed by a typical survey. The power spectrum of the survey window function is estimated by placing a large number of unclustered points, typically on the order of 100,000, within the angular area covered by the survey, using the radial selection function that is appropriate for the galaxy sample under consideration, as described above. As before, the different magnitude limits of the Schmidt plates in the Durham/UKST Survey are taken into account when the radial selection function is calculated.

Fig. 4 shows the power spectrum of the Durham/UKST Survey window function for various volume-limited and flux-limited samples. The top panel shows the power spectra of the window function for different volume-limited samples. The width of the window function power spectrum decreases as the volume limit adopted increases. Fig. 4(b) shows the window function power spectra of flux-limited samples. As the value of the power used in equation (1) is increased, the flux-limited sample has a larger effective depth and so the width of the window function is reduced. There is a relatively small change in the width of the survey window function when different samples of the data are considered. Defining the effective width of the window function as the wavenumber at which the power spectrum of the window function falls to half its maximum value, we obtain \(\delta k \sim 0.015 h^{-1}\) Mpc\(^{-1}\). At wavenumber separations smaller than this, our estimates of the power will be strongly correlated. For both flux limited and volume-limited samples, the window function power spectrum is a very steep power law at wavenumbers \(k \gg 0.06 h^{-1}\) Mpc\(^{-1}\), varying as \(k^{-4}\).

Figure 4. The power spectrum of the window function for different samples extracted from the Durham/UKST survey. In (a), the samples are volume limited with a maximum redshift of \(z_{\text{max}} = 0.05, 0.06, 0.07, 0.08\) reading from top to bottom. In (b), we plot the window function power spectrum for flux-limited samples. The weights applied are \(P = 32000, 16000, 8000, 4000\) and \(0 h^{-3}\) Mpc\(^3\) reading from top to bottom at \(\log k = -1.5\). For wavenumbers \(k \gg 0.06 h^{-1}\) Mpc\(^{-1}\), the window function power spectrum is a steep power law, \(\propto k^{-4}\).

3.3 Power spectrum estimation

The power spectrum estimator that we employ is a generalization of that given by equation (12) of Tadros & Efstathiou 1996 (see also Sutherland et al. 1999), to include the analysis of flux-limited samples. We do not reproduce the details of their derivation here.

The Fourier transform of the observed galaxy density field, within a periodic volume \(V\), is given by

\[
\hat{n}_{\text{gal}}(k) = \frac{1}{V} \sum \omega_{\text{gal}}(x_i) \exp(ik \cdot x_i),
\]

where the weight function \(\omega_{\text{gal}}(x_i)\) depends upon the type of galaxy sample under consideration. For the case of a volume-limited sample, \(\omega_{\text{gal}}(x_i) = 1\) for a galaxy that satisfies the criteria given in Section 3.1.2, and \(\omega_{\text{gal}}(x_i) = 0\) otherwise. For a flux-limited sample, \(\omega_{\text{gal}}(x_i)\) is given by equation (1).

The Fourier transform of the survey window function is
where $w_{\text{ran}}$ is the weight assigned to one of the unclustered points used to trace out the survey volume (note that the definition we have adopted for the Fourier transform of the survey window function differs by a factor of $1/h_{\text{ran}}$ from that given in equation (8) of Tadros & Efstathiou 1996, where $h_{\text{ran}}$ is the number density of unclustered points). The power spectra of the survey window function, shown in Fig. 4, are much steeper than the expected galaxy power spectrum, falling off as $\propto k^{-4}$ for wavenumbers $k > 0.06 h$ Mpc$^{-1}$. Therefore the main effect of the convolution with the survey window function is to alter the shape of the power spectrum only at wavenumbers $k < 0.06 h$ Mpc$^{-1}$.

Following Tadros & Efstathiou, we define a quantity with a mean value of zero:

$$\delta(k) = \hat{n}_g(k) - \alpha \hat{W}_g(k),$$

where $\alpha$ is the ratio of the number of galaxies to random points in volume-limited samples, or the ratio of the sum of the weights, given by equation (1), for galaxies and random points in flux-limited samples. The power spectrum of galaxy clustering is then estimated using

$$P_r(k) = \left[ \frac{V}{S_{\text{ran}}} \sum_{k'} (|W_{gal}(k')|^2 - 1/S_{\text{ran}}) \right]^{-1} \times \left( \frac{V^3|\delta(k')|^2 - 1/S_{\text{ran}}}{S_{gal}^2 - 1/S_{\text{gal}} - 1/S_{\text{ran}}} \right),$$

where we have used the notation $S_{gal} = \sum_{i=1}^{N_{gal}} w_{\text{gal}}^2$ and $S_{ran} = \sum_{i=1}^{N_{ran}} w_{\text{ran}}^2$. In the case of a volume-limited sample $S_{gal} = N_{gal}$, the number of galaxies in the sample, and $S_{ran} = N_{ran}$, the number of unclustered points used to define the survey window function.

The power spectra are computed by embedding the Durham/UKST volume into a larger cubical volume, $V$. The density field is typically binned onto a 256$^3$ mesh using nearest gridpoint assignment (we discuss the effects of aliasing and box size in Section 4). The Fourier transform is performed with an FFT.

3.4 Error analysis

We estimate the errors on the recovered power spectrum by constructing mock catalogues that have the same radial and angular selection as the Durham/UKST Survey and which have approximately the same clustering amplitude.

We extract mock Durham/UKST catalogues from the largest cosmological simulation performed to date, the ‘Hubble Volume’. The simulation uses $10^9$ particles in a volume of $8 \times 10^9 h^{-3}$ Mpc$^3$ and thus contains roughly 10,000 independent Durham/UKST Surveys volume-limited to $z_{\text{max}} = 0.06$. This allows a wide range of clustering environments to be explored, giving a good assessment of the size of the sampling variance for the Durham/UKST Survey.

The power spectrum of the Hubble Volume simulation is a variant of the standard CDM model known as rCDM. The shape of the power spectrum can be described by the parameter $\Gamma$, which is set to the value $\Gamma = 0.21$ for rCDM, compared with the standard CDM case where $\Gamma = 0.84$ (Baugh & Efstathiou 1993; Maddox, Efstathiou & Sutherland 1996). To make an accurate assessment of the errors in our recovered power spectrum we need to make mock catalogues in which the clustering matches as closely as possible that in the Durham/UKST Survey. To extract such catalogues from the Hubble Volume, we apply a simple biasing prescription to the density field. We first bin the density field onto a cubical grid of cell size $5 h^{-1}$ Mpc, using a nearest gridpoint assignment scheme. We then associate a probability with each grid cell that depends on the ratio of the cell density to the mean density, for selecting a mass particle from that cell to be a biased or ‘galaxy’ particle. The form of the probability that we adopt is the same as model 1 of Cole et al. (1998) (although these authors apply a Gaussian filter to

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Figure 5. The solid curve shows the linear power spectrum of the mass in the Hubble Volume simulation. The dotted curve shows the power spectrum of a subset of the particles in the simulation, selected according to the biasing prescription outlined in Section 3.4, measured in a cubical volume of side $375 h^{-1}$ Mpc. The dashed curve shows the power spectrum of these biased particles when the density is binned using redshift-space coordinates. The points show the power spectrum of APM-Survey galaxies, measured in real space.
smooth the density field – we have chosen the size of our cubical grid cell roughly to match the effective volume of the Gaussian filter:

\[ P(\nu) = \begin{cases} 
\exp(\alpha \nu + \beta \nu^3/2) & \text{if } \nu \gg 0 \\
\exp(\alpha \nu) & \text{otherwise}, 
\end{cases} \tag{7} \]

where \( \nu \) is the number of standard deviations away from the mean for the density in the cell and we set \( \alpha = 1.26 \) and \( \beta = -0.45 \).

The power spectrum of the biased set of particles is shown by the dotted curve in Fig. 5, which agrees well with the amplitude of the power spectrum of APM galaxies (Baugh & Efstathiou 1993; Gaztañaga & Baugh 1998). The dashed curve in Fig. 5 shows the power spectrum of the biased points when redshift-space distortions are also included in the positions of the galaxies. As expected, the power is increased on large scales and damped on small scales.

The errors on the Durham/UKST Survey power spectrum are taken to be the same size as the fractional errors on the mock catalogue power spectra. This is a valid assumption when either the contribution of shot noise to the power spectrum is negligible or, as in our case by design, the mock catalogue power spectrum and the Durham/UKST power spectrum have similar shapes and amplitudes. The errors obtained from the mock catalogues converge when averaged over 40 mock observers and are in reasonable agreement with the size of the errors obtained using the expression given in equation (2.4.6) of Feldman et al. (1994).

### 4 TESTS OF THE POWER SPECTRUM ESTIMATION

In this section, we make systematic tests of the power spectrum estimator (equation 6) in order to assess the range of wavenumbers over which we can make a robust measurement of the true power spectrum of galaxy clustering.

On large scales, there are two main effects that can cause the recovered power spectrum to differ from the true power spectrum. First, Fig. 4 shows that the assumption that the power spectrum of the survey window function is sharply peaked does not hold for wavenumbers \( k \ll 0.04 \, h \, \text{Mpc}^{-1} \). On these scales, the recovered power spectrum has a shape different from the underlying power spectrum; the convolution of the power spectrum of the survey window function with the true galaxy power spectrum alters both the shape and amplitude of the estimated power spectrum at these wavenumbers. Secondly, the number of galaxies used in equation (6) is estimated from the sample itself. If fluctuations in galaxy density exist on the scale of the survey, this number can be sensitive to the environment sampled by the mock catalogue, and hence can be different from the true mean galaxy density, which is obtained by considering a much larger volume. This leads to an underestimate of the power on large scales (Peacock & Nicholson 1991; Tadros & Efstathiou 1996), which is sometimes called the integral constraint. In addition, there will be a contribution to this effect from Poisson sampling noise, even in the absence of clustering on the scale of the survey.

The redshift-space power spectrum of biased tracers of the mass distribution in the Hubble Volume simulation is shown in Fig. 6. The mean power spectrum is obtained by averaging over 40 cubical volumes of side \( 375 \, h^{-1} \, \text{Mpc} \). The power spectrum averaged over 40 mock UKST catalogues made from the biased particles is shown by the open circles. The error bars show the 1σ variance over the 40 mock catalogues. We have used the number

![Figure 6](https://academic.oup.com/mnras/article-abstract/309/3/659/974342)

**Figure 6.** The solid curve shows the redshift-space power spectrum for biased particles from the Hubble Volume simulation, averaged over 40 cubical volumes of side \( 375 \, h^{-1} \, \text{Mpc} \). The open circles show the power spectrum averaged over 40 mock Durham/UKST catalogues, to a volume limit of \( z_{\max} = 0.06 \). The errorbars on these points are the 1σ errors for a single power spectrum extracted from the Durham/UKST Survey. The dashed curve shows the convolution of the mean power spectrum measured from the large cubical volumes (solid curve) with the window function of the survey.

![Figure 7](https://academic.oup.com/mnras/article-abstract/309/3/659/974342)

**Figure 7.** The points in (a) and (b) show the redshift-space power spectrum of biased particles averaged over 40 large cubical boxes extracted from the Hubble Volume simulation. (a) shows the effects of changing the size of the FFT grid when the mock catalogue is embedded in a fixed-size box of side \( 1600 \, h^{-1} \, \text{Mpc} \). The solid curve shows the result when the density grid has 256 cells per side, the dashed curve has 128 cells and the dotted curve has 64 cells. (b) shows the effects of varying the size of the transform box at a fixed FFT grid size of 256 cells per side. The solid curve shows the results for a transform box of \( 1600 \, h^{-1} \, \text{Mpc} \), the dashed curve for \( 800 \, h^{-1} \, \text{Mpc} \) and the dotted curve for \( 400 \, h^{-1} \, \text{Mpc} \).
of galaxies in the extracted mock catalogue to compute the number density of galaxies for use in the estimator (equation 6). There are still density fluctuations over volumes of the size of the Durham/UKST Survey, which leads to a variance in the number of galaxies between different mock observers and causes a bias in the power spectrum estimate at large scales. The dashed curve shows the convolution of the mean power spectrum averaged over large cubical volumes (shown by the solid curve) with the window function of the Durham/UKST Survey. This shows that the dominant effect on the shape of the power spectrum on large scales is the window function convolution rather than the integral constraint for the Durham/UKST Survey. The convolution with the window function power spectrum introduces curvature into the scales is the window function of the Durham/UKST Survey. This shows that the cubical volumes (shown by the solid curve) with the window function of the Durham/UKST Survey, which leads to a variance in the number of galaxies between different mock observers and causes a bias in the number density of galaxies for use in the estimator (equation 6).

In Fig. 7(a), we vary the dimension of the FFT grid fixed at 256$^3$. Fig. 7 shows that using a 256$^3$ FFT grid and a box size of 800 $h^{-1}$ Mpc, gives accurate results down to $k \sim 0.6 h^{-1}$ Mpc or 10 $h^{-1}$ Mpc. The power spectra estimated from the mock surveys are discrepant with the estimates from large cubical volumes at $k \approx 0.04 h^{-1}$ Mpc owing to the convolution with the survey window function.

As we cannot infer the true mean density of galaxies from the single observed realization of the galaxy distribution that we have (equivalently, we do not know the shape of the true power spectrum on these scales), we do not attempt to correct the power spectrum at large scales for either the ‘integral constraint’ bias or for the convolution with the power spectrum of the survey window function. Instead, our tests in this section demonstrate that our estimates of the power spectrum for the Durham/UKST Survey should be a robust measurement of the true galaxy power spectrum over the wavenumber range 0.04 $h^{-1}$ Mpc $\approx k \approx 0.63 h^{-1}$ Mpc; this corresponds to a wavelength range defined as $\lambda = 2\pi/k$, of 160 $h^{-1}$ Mpc to 10 $h^{-1}$ Mpc; the latter is roughly the mean separation of galaxies in a volume-limited sample.

## 5 RESULTS

In this section, we analyse volume-limited and flux-limited samples drawn from the Durham/UKST Galaxy Redshift Survey. In all cases, the power spectra are computed by embedding the

| $k$ ($h$ Mpc$^{-1}$) | $P(k)_{\text{int},z=0.06}$ | 1σ | $P(k)_{\text{flux},P=4000}$ | 1σ | $P(k)_{\text{flux},P=8000}$ | 1σ |
|-----------------|-----------------|-----|-----------------|-----|-----------------|-----|
| 0.0411          | 16153           | 12867| 24828           | 8946| 26962           | 9936|
| 0.0561          | 17014           | 10170| 23596           | 7805| 24177           | 8556|
| 0.0711          | 13927           | 6467 | 19763           | 6602| 19775           | 7243|
| 0.0860          | 12215           | 4672 | 15992           | 4880| 17049           | 5684|
| 0.1000          | 11096           | 3550 | 11332           | 3262| 12091           | 3606|
| 0.1078          | 9974            | 2962 | 9645            | 2635| 10103           | 2960|
| 0.1161          | 8682            | 2363 | 7991            | 2011| 8113            | 2353|
| 0.1251          | 7137            | 1973 | 7446            | 1836| 7732            | 2190|
| 0.1348          | 5707            | 1571 | 7065            | 1667| 7481            | 2065|
| 0.1452          | 4546            | 1168 | 6986            | 1515| 7464            | 2009|
| 0.1565          | 4153            | 934  | 5782            | 1339| 6012            | 1670|
| 0.1686          | 3937            | 825  | 4477            | 1149| 4547            | 1351|
| 0.1817          | 3713            | 798  | 3566            | 998 | 3553            | 1150|
| 0.1958          | 3305            | 727  | 3171            | 871 | 3170            | 1051|
| 0.2110          | 2750            | 549  | 2582            | 649 | 2696            | 854 |
| 0.2273          | 2189            | 413  | 2039            | 511 | 2230            | 733 |
| 0.2449          | 1790            | 371  | 2034            | 530 | 2289            | 779 |
| 0.2639          | 1517            | 339  | 1934            | 540 | 2112            | 722 |
| 0.2844          | 1247            | 234  | 1572            | 470 | 1727            | 626 |
| 0.3064          | 1091            | 184  | 1221            | 371 | 1251            | 456 |
| 0.3302          | 932             | 191  | 997             | 372 | 1028            | 474 |
| 0.3558          | 907             | 224  | 1262            | 498 | 1451            | 827 |
| 0.3834          | 826             | 209  | 882             | 360 | 929             | 514 |
| 0.4131          | 745             | 211  | 667             | 251 | 594             | 314 |
| 0.4451          | 615             | 213  | 421             | 156 | 344             | 199 |
| 0.4796          | 331             | 119  | 311             | 175 | 239             | 237 |
| 0.5168          | 181             | 87   | 339             | 170 | 338             | 279 |
| 0.5568          | 305             | 196  | 239             | 199 | 206             | 304 |
| 0.6000          | 339             | 252  | 111             | 115 | 40              | 89  |
survey in a box of side $840 h^{-1}$ Mpc and binning the density of galaxies on a grid of 256 cells on a side. We have rebinned the estimated power spectrum in bins of width $\delta k = 0.015 h$ Mpc$^{-1}$, roughly the width at half maximum of the survey window function, in order to reduce the correlations between the estimated power at adjacent wavenumbers. Selected results are given in Table 1.

The power spectra of different volume-limited samples of the Durham/UKST Survey are shown in Fig. 8. The error bars are computed using the fractional variance in the power averaged over mock catalogues extracted from the Hubble Volume simulation. These mock catalogues were made for each volume limit. As discussed in Section 3.4, these catalogues satisfy the same selection criteria and have approximately the same clustering as the Durham/UKST Survey galaxies. Varying the maximum redshift used to define the volume-limited catalogue has two effects on the properties of the extracted sample. Increasing $z_{\text{max}}$ increases the depth of the sample, thereby allowing fluctuations on larger scales to be probed. At the same time, however, the corresponding absolute magnitude limit imposed on the galaxies gets brighter. This means that the population of galaxies used to map out the clustering varies and it is possible that intrinsically bright galaxies could be more strongly clustered than faint galaxies (Park et al. 1994; Loveday et al. 1995). There is a shift in the amplitude of the power spectrum as larger values of $z_{\text{max}}$ are considered. However, the power spectra of the different samples are all consistent within the 1$\sigma$ errors.

The clustering in the flux limited Durham/UKST Survey is shown in Fig. 9. Again, the error bars show the 1$\sigma$ errors obtained from the fractional variance over the power estimated from mock catalogues made with the same selection criteria. The different panels are for weight functions (equation 1) using a range of constant values for the power spectrum, as indicated in the legend on each panel. Increasing the value of the power used in the weight causes the weight function to rise at progressively larger distances (see fig. 3 of Feldman et al. 1994). This means that the effective volume probed increases and thus the sensitivity to longer wavelength fluctuations increases.

If there are no systematic problems with the survey, changing the value of the power used in the weight function defined by equation (1) should have little effect upon the amplitude of the recovered power spectrum (see the power spectrum analysis of the combined 1.2 Jy and QDOT surveys by Tadros & Efstathiou 1995). However, the size of the errors on a particular scale will change, depending upon whether or not the choice of weight function used really is the minimum variance estimator for the power amplitude at these scales.

The curve that is reproduced in each panel of Fig. 9 shows the power estimated for a weight function with $P(k) = 8000 h^{-3}$ Mpc$^3$. This reference curve shows that there is a negligible change in the mean power when this weight is varied by a factor of eight over the range $P(k) = 4000$–$32000 h^{-3}$ Mpc$^3$. The flux-limited power spectrum with a weight $P(k) = 4000 h^{-3}$ Mpc$^3$ has the smallest errorbars over the range of wavenumbers plotted, though the errors are not significantly larger for the other estimates of the power spectrum. The errors on the power spectrum measured from the volume-limited sample with $z_{\text{max}} = 0.06$ are larger than the errors on the power obtained from the flux-limited sample for wavenumbers $k < 0.1 h$ Mpc$^{-1}$; however, for wavenumbers $k > 0.1 h$ Mpc$^{-1}$ the power spectrum of the volume-limited sample has smaller errors.

---

**Figure 8.** The Durham/UKST Survey power spectrum for different volume-limited samples. The error bars are the 1$\sigma$ variance obtained from the fractional errors on the power found in mock catalogues with the same angular and radial selection and approximately the same clustering. The power spectra are estimated using a box of side $840 h^{-1}$ Mpc and a 256$^3$ FFT grid. The solid curve is the mean power for a volume limit defined by $z_{\text{max}} = 0.06$, the sample that contains the most galaxies, and is reproduced in each panel.

**Figure 9.** The flux-limited Durham/UKST Survey power spectrum for different constant values of $P(k)$ used in the weight function given in equation (1). The values of $P(k)$ used are 4000, 8000, 16000 and 32000$ h^{-3}$ Mpc$^3$ as marked in the panels. The errorbars show the 1$\sigma$ variance obtained from mock catalogues with the same selection and similar clustering. The solid curve is the power spectrum for a weight with $P(k) = 8000 h^{-3}$ Mpc$^3$ and is reproduced in all the panels. The power spectra are computed in a box of side $840 h^{-1}$ Mpc using a 256$^3$ density grid.
The comparison between the power spectra of the flux-limited and volume-limited samples is difficult to interpret. Neither the volume nor the way in which the volume is weighted can be simply related between the two methods for constructing galaxy samples. Furthermore, volume-limited samples select intrinsically brighter galaxies as the volume is increased and it is possible that these galaxies could have different clustering properties compared with fainter galaxies. Nevertheless, the agreement between the power spectra measured from the flux- and volume-limited samples is very good; if we compare the power spectrum from the volume-limited sample with \( z_{\text{max}} = 0.06 \) (which contains the most galaxies), and the power spectrum with the smallest errors from the flux-limited survey (i.e. with a value of \( P(k) = 4000 h^{-3} \text{Mpc}^3 \) used in the weight function), then the level of agreement is within the 1\( \sigma \) errors. This is a further argument against a significant dependence of clustering strength upon intrinsic luminosity within the survey.

6 COMPARISON WITH OTHER MEASUREMENTS OF THE POWER SPECTRUM

We compare our results with measurements of the power spectrum made from other surveys in Figs 10, 11 and 12. In Fig. 10, we compare the power spectrum from a sample of the Durham/UKST Survey, defined by a volume limit of \( z_{\text{max}} = 0.06 \) (filled circles) with the power spectrum of a sample drawn from the Stromlo–APM Survey (Tadros & Efstathiou 1996) with the same selection (open circles). The two estimates of the power spectrum are in remarkably good agreement, except near wavenumbers of \( \log k = -0.8, -0.5 \) and \(-0.3 \), where there are sharp dips in the Stromlo–APM power spectrum. The solid curve shows the real-space power spectrum measured from the APM Survey (Baugh & Efstathiou 1993), which is below the power spectra measured from the redshift surveys. We compare estimates of the power spectrum made from flux-limited samples in Fig. 11. Again, the filled circles show the power spectrum of the Durham/UKST Survey, the open circles show the power spectrum of the Stromlo–APM Survey, and the crosses show the power spectrum measured from the Las Campanas Survey.

![Figure 10](https://example.com/figure10.png)

**Figure 10.** The Durham/UKST Survey volume-limited power spectrum (solid points) compared with the power spectrum of the Stromlo–APM Survey (Tadros & Efstathiou 1996); in both cases, the volume limit is defined by \( z_{\text{max}} = 0.06 \). The solid curve shows the real-space APM galaxy power spectrum from Baugh & Efstathiou (1993).

![Figure 11](https://example.com/figure11.png)

**Figure 11.** The flux-limited, \( P = 8000 h^{-3} \text{Mpc}^3 \), power spectrum of the Durham/UKST Survey (solid points) compared with the flux-limited power spectra of other optical samples. The open circles show the power spectrum of the Stromlo–APM Survey (Tadros & Efstathiou 1996), again flux limited with \( P = 8000 h^{-3} \text{Mpc}^3 \) and the crosses show the deconvolved \( P(k) \) from the Las Campanas Redshift Survey from Lin et al. (1996).

![Figure 12](https://example.com/figure12.png)

**Figure 12.** The power spectrum of Durham/UKST galaxies (filled circles) compared with the power spectrum (open circles) of IRAS galaxies obtained from the combined 1.2 Jy and QDOT Surveys by Tadros & Efstathiou (1995). Both power spectra are measured from flux-limited samples and are minimum-variance estimates for the respective surveys. The curve shows the IRAS power spectrum after multiplying by a relative bias factor squared of \( b_{\text{rel}} = 1.3 \), where we have assumed that the bias factor is not a function of scale.
(Lin et al. 1996). The Durham/UKST and Stromlo–APM Surveys have similar magnitude limits, \( b_J \sim 17 \), whereas the Las Campanas Survey is approximately 1–1.5 magnitudes deeper, going to an \( R \)-band magnitude of 17.3–17.7, depending upon the spectrograph used to measure redshifts in a particular field. The Las Campanas survey consists of six \( 1.5 \times 80 \text{ deg}^2 \) strips and an attempt has been made to deconvolve the survey window function to give the estimate of the power spectrum plotted here (Lin et al. 1996). The power spectra from flux-limited samples are in good agreement down to a wavenumber of \( \log k = -1.1 \) or for scales \( \lambda < 80 \text{ h}^{-1} \text{ Mpc} \). On larger scales than this, the power spectrum measured from the Las Campanas Survey is below that obtained from the Durham/UKST and Stromlo–APM Surveys, which continue to rise to \( \lambda = 150 \text{ h}^{-1} \text{ Mpc} \). On scales larger than this, the convolution with the survey window function of these surveys affects the shape of the recovered power spectrum. Note that the weighting scheme used to estimate the Las Campanas power spectrum is different from that employed in this paper, with each galaxy weighted by the inverse of the selection function.

In Fig. 12, we compare the power spectrum of the Durham/UKST Survey, which is an optically selected sample, with the power spectrum obtained from an analysis by Tadros & Efstathiou (1995) of the combined 1.2-Jy Survey (Fisher et al. 1995) and QDOT Survey (Efstathiou et al. 1990a) data sets, which are selected in the infrared from the IRAS point source catalogue. We have plotted the minimum variance estimate of the power spectrum obtained for each data set. The filled circles show the Durham/UKST power spectrum and the open circles show the power spectrum of IRAS galaxies. The IRAS galaxy power spectrum has a lower amplitude than the Durham/UKST power spectrum. The solid curve shows the result of multiplying the IRAS power spectrum points by a constant, relative bias factor squared of \( b_{rel} = 1.3 \), which agrees with the value inferred by Peacock & Dodds (1994).

### 7. IMPLICATIONS FOR MODELS OF LARGE-SCALE STRUCTURE

In this section we compare the predictions of various scenarios for the formation of large-scale structure in the Universe with the power spectrum of the Durham/UKST Survey.

There are several steps that one has to go through in order to compare a power spectrum for the mass distribution, calculated in linear perturbation theory, with a galaxy power spectrum measured using the positions of the galaxies inferred from their redshifts. These steps are given as follows.

(i) Compute the non-linear power spectrum of the mass distribution given the amplitude of rms density fluctuations specified by the value of \( \sigma_8 \). We use the transformation given by Peacock & Dodds (1996).

(ii) Choose a bias parameter, \( b \), relating fluctuations in the mass distribution to fluctuations in the galaxy distribution: \( P_{\text{gal}}(k) = b^2 P_{\text{mass}}(k) \). In the following analysis we make the simplifying assumption that the bias parameter is independent of scale.

(iii) Model the distortion of clustering due to the fact that galaxy redshifts have a contribution from motions introduced by inhomogeneities in the local gravitational field of the galaxy as well as from the Hubble flow.

(iv) Convolve the power spectrum with the window function of the Durham/UKST survey.

On large scales, (iii) leads to a boost in the amplitude of the power spectrum (Kaiser 1987), whilst on small scales the power is damped by random motions inside virialized groups and clusters. It is important to model these two extremes and the transition between them accurately, as this can have a significant effect on the shape of the power spectrum over the range of scales that we consider. We model the effects of the peculiar motions of galaxies on the measured power spectrum using the formula given by Peacock & Dodds (1994):

\[
P_{\text{gal}}(k) = b^2 P(k) G(\beta, y),
\]

where \( P_{\text{gal}}(k) \) is the galaxy power spectrum measured in redshift space and \( P(k) \) is the mass power spectrum measured in real space. The function \( G(\beta, y) \), where \( \beta = \Omega m / b \) and \( y = k \sigma / 100 \) (\( \sigma \) is the one-dimensional velocity dispersion), is given by

\[
G(\beta, y) = \frac{\sqrt{\pi} \text{erf}(y)}{8y^3} (3\beta^2 + 4\beta y^2 + 4y^4) - \frac{\exp(-y^2)}{4y^4} [\beta^2 (3 + 2y^2) + 4\beta y^2].
\]

This assumes that the small scale peculiar velocities of galaxies are independent of separation and have a Gaussian distribution.

We compare the models with the Durham/UKST power spectrum measured from a sample with a volume limit defined by \( z_{\text{min}} = 0.06 \). This power spectrum measurement has larger errors than the minimum variance power spectrum from the flux-limited sample on large scales, \( \lambda = 2\pi / k \sim 60 \text{ h}^{-1} \text{ Mpc} \). However, on scales smaller than this, the volume-limited power spectrum has the smallest errors. Furthermore, the fractional errors in the power are smallest at high wavenumbers, because these waves are better sampled by the survey, and so it is these scales that are the most important for constraining the parameters in our model.

![Figure 13. The open circles show the mean power averaged over 10 mock Durham/UKST Surveys in real space and the filled circles are in redshift space. The curves show the Peacock and Dodds predictions (equation 8) with a bias of \( b = 1.5 \) and \( \sigma = 300 \text{ km s}^{-1} \) (long dashed), \( \sigma = 500 \text{ km s}^{-1} \) (solid) and \( \sigma = 1000 \text{ km s}^{-1} \) (short dashed).](https://academic.oup.com/mnras/article-abstract/309/3/659/974342)
We test our simple model for the transformation of a linear-theory power spectrum for mass fluctuations to a galaxy power spectrum measured in redshift space in Fig. 13. The open circles show the mean power spectrum from 10 Durham/UKST mock catalogues, using the real-space coordinates of the particles to map out the density. The filled circles show the distortion caused to the power spectrum when the peculiar motions of the particles are included. The curves show the results of applying equation (8) to the non-linear $\sigma$CDM power spectrum. This equation results from performing an azimuthal average over the angle between the line of sight and the wavevector of the density fluctuation. The observer is also assumed to be at an infinite distance away from the wave. These two assumptions will mainly affect the longest wavelength fluctuations in a real survey that does not cover the whole sky. These scales are already distorted by the convolution with the survey window function. The model provides a reasonably good fit for a one-dimensional velocity dispersion of $\sigma = 500\,\text{km\,s}^{-1}$, which is approximately the value found in the simulation (Jenkins et al. 1998).

The first test we perform is to compare the power spectrum of APM Survey galaxies (Baugh & Efstathiou 1993, 1994a; Gaztañaga & Baugh 1998) with the Durham/UKST volume-limited power spectrum. The APM power spectrum is measured in real space and is estimated by inverting the angular correlation function of APM galaxies with $17 < b_j < 20$. The shapes of the real-space and redshift-space power spectra can be compared in Fig. 14(a). The real-space power spectrum is shown by the dashed curve, after multiplying by a constant factor of 1.4 to match the Durham/UKST Survey at small wavenumbers, so that the relative shapes of the real-space and redshift-space power spectra can be readily compared. We have rebinned the Durham/UKST power spectrum and error bars to match the binning of the APM $P(k)$, which has $\delta \log k = 0.13$. The spacing of the power spectrum measurements is now much larger than the half width of the survey window function, so there is essentially no covariation between the errors at different wavenumbers. The rebinned Durham/UKST power spectrum is shown in each panel of Fig. 14 by the points and errorbars. We retain this binning of the Durham/UKST power spectrum in the subsequent analysis of theoretical power spectra below. As we are comparing two galaxy power spectra, we omit the factor of $b^2$ in equation (8). The best-fitting APM galaxy power spectrum, including the redshift-space distortions, is shown by the solid curve in Fig. 14(a). The transformation into redshift space removes the inflection in the real-space APM power spectrum around a wavenumber of $k \sim 0.15\,\text{h\,Mpc}^{-1}$. The best-fitting values of $\beta$ and $\sigma$, with 1$\sigma$ errors, are $\beta = 0.60 \pm 0.35$ and $\sigma = 320 \pm 140\,\text{km\,s}^{-1}$. Tadros & Efstathiou (1996) found $\beta = 0.38 \pm 0.06$ by comparing the Stromlo–APM redshift-space power spectrum to the APM Survey power spectrum, restricting their attention to wavenumbers in the range $0.05 < k < 0.1\,\text{h\,Mpc}^{-1}$, on which they argued that the damping of power in redshift space is negligible. The one-dimensional velocity dispersion that we recover from the comparison is in excellent agreement with the measurement of Ratcliff et al. (1998d), but has much larger errors. By considering the galaxy correlation function binned in separation parallel and perpendicular to the line of sight, Ratcliffe et al. obtained a value for the pairwise rms velocity dispersion along the line of sight $\sigma_t = 416 \pm 36\,\text{km\,s}^{-1}$. This quantity is approximately $\sqrt{2}$ times the one-dimensional velocity dispersion that we use, giving $\sigma = 294 \pm 25\,\text{km\,s}^{-1}$. If we add in quadrature the estimated error in the measured redshifts $\sim 150\,\text{km\,s}^{-1}$ (Ratcliffe et al. 1998a), the Ratcliffe et al. measurement implies $\sigma = 330\,\text{km\,s}^{-1}$.

We also test four popular CDM models by treating the bias parameter and the one-dimensional velocity dispersion as free parameters. The mass power spectra use the transfer function given in Efstathiou et al. (1992). The models that we consider are: $\Omega_0 = 1$ CDM with a shape parameter $\Gamma = 0.5$ and with a normalization of $\sigma_8 = 0.52$ (SCDM) that reproduces the local abundance of rich clusters (Eke et al. 1996); a model with a normalization of $\sigma_8 = 1.24$ and $\Gamma = 0.5$ (COBE-SCDM), which matches the COBE detection of temperature anisotropies in the microwave background, but seriously over-predicts the abundance of hot clusters; $\tau$CDM, with $\Omega_0 = 1$, $\Gamma = 0.2$ and $\sigma_8 = 0.52$, which simultaneously matches the amplitude implied by COBE and by the cluster abundance through an adjustment to the shape of the power spectrum, as described in Section 3.4, and $\Lambda$CDM, which is a low-density model, with a present day value for the density parameter of $\Omega_0 = 0.3$ and a cosmological constant of $\Lambda_0/3H_0^2 = 0.7$ (Efstathiou, Sutherland & Maddox 1990b). The $\Lambda$CDM model has a normalization of $\sigma_8 = 0.93$.

The best-fitting parameters are given in Table 2. Note that, as we specify a value for the density parameter $\Omega_0$ through our choice of structure formation model, we are constraining the value of the bias parameter $b$; the implied errors on $\beta$ are much smaller than if we had not selected a value for $\Omega_0$ beforehand. For all the models considered, reasonable agreement with the Durham/UKST Survey power spectrum can be obtained if no restrictions are placed on the values of the bias and one-dimensional velocity dispersion that are used in the fit. However, the SCDM and COBE-CDM models only produce a reasonable fit to the Durham/UKST power spectrum if large values of the velocity dispersion are adopted; these values are inconsistent with the value we obtain.

![Figure 14](https://academic.oup.com/mnras/article-abstract/309/3/659/974342/10.1093/mnras/309.3.659)

**Figure 14.** The points in each panel show the Durham/UKST power spectrum for a volume-limited sample with $z_{\text{max}} = 0.06$. The power spectrum estimates have been rebinned to reduce the covariance in the errors. In (a), the dashed curve shows the APM galaxy power spectrum measured in real space, rescaled to match the Durham/UKST power spectrum at large scales. The solid curve shows the APM power spectrum, including the effects of distortion in redshift space. The remaining panels, b, c, d, show the best-fitting curves for several variants of the Cold Dark Matter model. Table 2 gives the values of the linear bias $b$ and the one-dimensional velocity dispersion $\sigma$ used in equation (9).
from the comparison with the APM survey power spectrum at more than 3σ. The velocity dispersion required for the ΛCDM model is marginally inconsistent (1.5σ) with the value that we infer from the comparison with the APM power spectrum. This agrees with the results of the complementary analysis of the two-point correlation function carried out by Ratcliffe et al. (1998c), who analysed the clustering in a N-body simulation with a very similar cosmology and power spectrum. The τCDM model gives the best fit to the Durham/UKST data in the sense that the values of β and σ required are in excellent agreement with those obtained from the comparison with the real-space galaxy power spectrum.

8 CONCLUSIONS

There is remarkably good agreement between measurements of the power spectrum of galaxy clustering made from optically selected surveys, on scales up to λ = 80 h⁻¹ Mpc. On larger scales than this, the most recently completed surveys cover a large enough volume to permit useful estimates of the power spectrum to be made. For scales larger than λ = 80 h⁻¹ Mpc, we find good agreement between the power spectra of the Durham/UKST Survey and of the Stromlo-APM Survey (Tadros & Efstathiou 1996). We measure more power on these scales than is found in a clustering analysis of the Las Campanas Redshift Survey (Lin et al. 1996). We find no convincing evidence for a dependence of galaxy clustering on intrinsic luminosity within the Durham/UKST Survey. However, we do measure a higher amplitude for the power spectrum from our optically selected sample compared with that recovered for galaxies selected by emission in the infrared; the offset in amplitude can be described by an optical/infrared bias factor of βrel = 1.3.

We have compared the shape and amplitude of the APM survey power spectrum (Baugh & Efstathiou 1993, 1994b; Gaztañaga & Baugh 1998), which is free from any distortions caused by peculiar velocities, with the Durham/UKST power spectrum. The APM power spectrum displays an inflection at k ~ 0.15 h Mpc⁻¹. Using a simple model for the effects of galaxy-peculiar velocities that is valid over a wide range of scales, we find that the inflection is flattened out in redshift space. The APM power spectrum can be distorted to give a good match to the Durham/UKST power spectrum for β = Ω₀^{0.6}/b = 0.60 ± 0.35 and a one-dimensional velocity dispersion of σ = 340 ± 120 km s⁻¹. These values are consistent with those found from an independent analysis of clustering in the Durham/UKST Survey by Ratcliffe et al. (1998d), who obtained β = 0.52 ± 0.39 (see Hamilton 1998 and references therein for estimates of β made from different surveys using a range of techniques) and v₁σ(−√2σ) = 416 ± 36 km s⁻¹. The value of β that we obtain from this analysis can be used, with an assumption for the value of Ω₀, to infer the amplitude of fluctuations in the underlying mass distribution. For example, if we assume Ω₀ = 1, our value for β suggests that APM galaxies are biased with respect to fluctuations in the mass by b = 1.7 ± 1.0; this in turn implies a value for the rms fluctuations in mass of σ₁ = 0.84/b = 0.50 ± 0.29, which is consistent with that required to reproduce the abundance of massive clusters (Eke et al. 1996). As the abundance of clusters and β have a similar dependence on Ω₀, this agreement will hold for any value of Ω₀ and therefore does not constrain Ω₀.

We have compared theoretical models for structure formation with the power spectrum of the Durham/UKST survey. The best agreement is found with a variant of the Cold Dark Matter model known as τCDM. A low-density model with a cosmological constant also provides reasonable agreement, but for a velocity dispersion that is marginally inconsistent with that obtained from our comparison between the power spectra of the Durham/UKST and APM Surveys. Critical density CDM models with shape parameter Γ = 0.5 require one-dimensional velocity dispersions that are much too high in order to provide a good fit to the Durham/UKST power spectrum. One possible way to resolve this problem would be to relax the assumption that the bias parameter between galaxies and the mass distribution is independent of scale. Whilst a constant bias is undoubtedly a poor approximation on scales around a few megaparsecs and smaller (see for example Benson et al. 1999), our analysis probes scales greater than 20 h⁻¹ Mpc. A scale-dependent bias on such large scales could be motivated in a cooperative galaxy formation picture (Bower et al. 1993), though the higher-order moments of the galaxy distribution expected in such a model are notfavoured by current measurements (Frieman & Gaztañaga 1994).

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