The 2dF Galaxy Redshift Survey: Cosmological Parameters and Galaxy Biasing

Ofer LAHAV & the 2dFGRS team
Institute of Astronomy, University of Cambridge, Madingley Road, Cambridge CB3 0HA, UK

Abstract

The 2dF Galaxy Redshift Survey (2dFGRS) has already measured over 220,000 redshifts of nearby ($z \sim 0.1$) galaxies. It allows us to estimate fundamental cosmological parameters and to subdivide the survey into subsets according to the galaxy intrinsic properties. The large-scale structure analysis of the survey has already yielded several significant results: (i) the shape of the power spectrum of fluctuations is consistent with the Λ-Cold Dark Matter concordance model; (ii) from joint analysis of the 2dFGRS data with the Cosmic Microwave Background anisotropies the linear-theory rms mass fluctuations is $\sigma_{8\mathrm{m}} \approx 0.73$, lower than the COBE-alone normalization and previous estimates from cluster abundance and cosmic shear; (iii) The biasing parameter of bright galaxies on scales $\gtrsim 10\,h^{-1}$ Mpc is nearly unity; and (iv) on scales smaller than $\lesssim 10\,h^{-1}$ Mpc red galaxies are more strongly clustered than blue galaxies.

1. Introduction

Multifibre technology now allows us to measure redshifts of millions of galaxies. The Anglo-Australian 2 degree Field Galaxy Redshift Survey* (2dFGRS) has already measured redshifts for 220,000 galaxies selected from the APM catalogue (as of March 2002). The median redshift of the 2dFGRS is $\bar{z} \sim 0.1$. It aims to acquire a complete sample of ~250,000 galaxy spectra, down to an extinction corrected magnitude limit of $b_J < 19.45$ (Colless et al. 2001). A sample of this size allows large-scale structure statistics to be measured with very small random errors. In this review we summarize some recent results from the

---

*The 2dFGRS Team comprises: I.J. Baldry, C.M. Baugh, J. Bland-Hawthorn, T.J. Bridges, R.D. Cannon, S. Cole, C.A. Collins, M. Colless, W.J. Couch, N.G.J. Cross, G.B. Dalton, R. DePropris, S.P. Driver, G. Efstathiou, R.S. Ellis, C.S. Frenk, K. Glazebrook, E. Hawkins, C.A. Jackson, O. Lahav, I.J. Lewis, S.L. Lumsden, S. Maddox, D.S. Madgwick, S. Moody, P. Norberg, J.A. Peacock, B.A. Peterson, W. Sutherland, K. Taylor. For more details on the survey see http://www.mso.anu.edu.au/2dFGRS/

2dFGRS on clustering and galaxy biasing.

2. The Power spectrum of 2dF Galaxies

An initial estimate of the convolved, redshift-space power spectrum of the 2dFGRS has already been determined (Percival et al. 2001; hereafter P01) for a sample of 160,000 redshifts. On scales $0.02 < k < 0.15\,h\,\mathrm{Mpc}^{-1}$, the data are robust and the shape of the power spectrum is not affected by redshift-space or non-linear effects, though the amplitude is increased by redshift-space distortions. P01 and Efstathiou et al. (2002; hereafter E02) have mainly compared the *shape* of the 2dFGRS and CMB power spectra, and concluded that they are consistent with each other (see also Tegmark, Hamilton & Xu 2001), within the Λ-CDM framework.

Lahav et al. (2001) have estimated the *amplitudes* of the linear-theory rms fluctuations in mass $\sigma_{8\mathrm{m}}$ and in galaxies $\sigma_{8\mathrm{g}}$. More precisely, consider the ratio of galaxy to matter power spectra, and use the ratio of these to define the bias parameter:

$$b^2 \equiv \frac{\sigma_{8\mathrm{g}}^2}{\sigma_{8\mathrm{m}}^2} \equiv \frac{P_{\mathrm{gg}}(k)}{P_{\mathrm{mm}}(k)} \tag{1}$$

On scales of $0.02 < k < 0.15\,h\,\mathrm{Mpc}^{-1}$ the fluctuations are close to the linear regime, and there are good reasons (e.g. Benson et al. 2000) to expect that b should tend to a constant. Here we do not test the assumption that the biasing is scale-independent, but we do allow it to be function of luminosity and redshift. Another necessary complication is that we need to distinguish between the apparent values of $\sigma_{8\mathrm{g}}$ as measured in redshift space ($\sigma_{8\mathrm{g}}^S$) and the real-space value that would be measured in the absence of redshift-space distortions ($\sigma_{8\mathrm{g}}^R$). It is the latter value that is required in order to estimate the bias. We emphasize that here $\sigma_{8\mathrm{g}}$ is the linear-theory normalization, not the observed non-linear $\sigma_{8\mathrm{gNL}}$. For example, the 2dFGRS correlation function of Norberg et al. (2001a) can be translated to a non-linear $\sigma_{8\mathrm{gNL}}^R(L_*) = 0.87 \pm 0.07$, at an effective redshift of approximately 0.07. In practice, nonlinear corrections to σ_8 are expected to be relatively small for CDM-like spectra.

The 2dFGRS power spectrum (Fig. 1) is fitted in P01 over the above range in k, assuming scale-invariant primordial fluctuations and a Λ-CDM cosmology, for four free parameters: $\Omega_{\mathrm{m}}h$, $\Omega_{\mathrm{b}}/\Omega_{\mathrm{m}}$, h and the redshift space $\sigma_{8\mathrm{g}}^S$. Assuming a Gaussian prior on the Hubble constant $h = 0.7 \pm 0.07$ (based on Freedman et al. 2001) the shape of the recovered spectrum within the above k-range was used to yield 68 per cent confidence limits on the shape parameter $\Omega_{\mathrm{m}}h = 0.20 \pm 0.03$, and the baryon fraction $\Omega_{\mathrm{b}}/\Omega_{\mathrm{m}} = 0.15 \pm 0.07$, in accordance with the popular

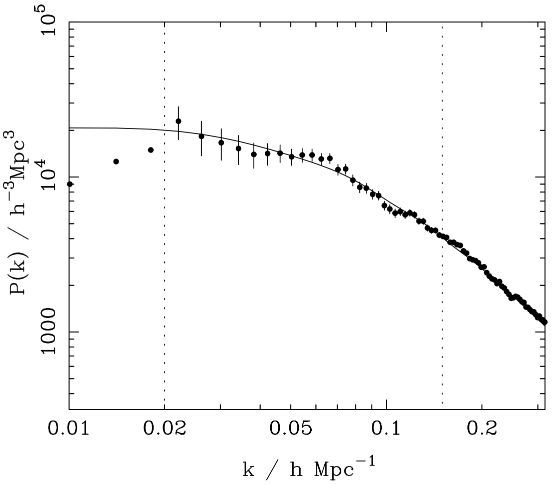

Fig. 1. The observed (i.e. convolved with the window function) 2dFGRS power spectrum (as derived in Percival et al. 2001). The solid line shows a linear theory Λ-CDM fit (convolved with the window function) with $\Omega_{\rm m}h = 0.2, \Omega_{\rm b}/\Omega_{\rm m} = 0.15, h = 0.7, n = 1$ and best-fitting $\sigma_{8{\rm g}}^S(z_s, L_s) = 0.94$. Only the range $0.02 < k < 0.15\,h\,{\rm Mpc}^{-1}$ is used at the present analysis (roughly corresponding to CMB harmonics $200 < \ell < 1500$ in a flat $\Omega_{\rm m} = 0.3$ Universe). The good fit of the linear theory power spectrum at $k > 0.15\,h\,{\rm Mpc}^{-1}$ is due to a conspiracy between the non-linear growth and finger-of-god smearing.

'concordance' model. For fixed 'concordance model' parameters $n = 1, \Omega_{\rm m} = 1 - \Omega_\Lambda = 0.3$, $\omega_{\rm b} = 0.02$ and a Hubble constant $h = 0.70$, we find that the amplitude of 2dFGRS galaxies in redshift space is $\sigma_{8{\rm g}}^S(L_s, z_s) \approx 0.94$. As shown in P01, the likelihood analysis gives a second (non-standard) solution, with $\Omega_{\rm m}h \sim 0.6$, and the baryon fraction $\Omega_{\rm b}/\Omega_{\rm m} = 0.4$, which generates baryonic 'wiggles'. We ignore this case at the present analysis. We also note that even if there are features in the primordial power spectrum, they would get washed out by the 2dFGRS window function (Elgaroy, Gramann & Lahav 2002).

In reality, the effective redshift for the P01 analysis is not zero, but $z_s \sim 0.17$. This is higher than the median redshift of 2dFGRS ($z_m \sim 0.11$) due to the weighting scheme used in estimating the power spectrum. Similarly, $L_s \simeq 1.9L_*$, rather than the $L_s \simeq L_*$ that would apply for a flux-limited sample. The effects of redshift-space distortion, evolution of biasing and luminosity bias on the determination of b are quite significant, at the level of ~ 15 per cent each.

3. Combining 2dFGRS & CMB

A simultaneous analysis of the constraints placed on cosmological parameters by different kinds of data is essential because each probe (e.g. CMB, SNe Ia, redshift surveys, cluster abundance, and peculiar velocities) typically constrains a different combination of parameters (e.g. Bahcall et al. 1999; Bridle et al. 2001a; E02). A particular case of joint analysis is that of galaxy redshift surveys and the CMB. While the CMB probes the fluctuations in matter, the galaxy redshift surveys measure the perturbations in the light distribution of particular tracer (e.g. galaxies of certain type). Therefore, for a fixed set of cosmological parameters, a combination of the two can tell us about the way galaxies are 'biased' relative to the mass fluctuations (e.g. Webster et al. 1998).

The CMB fluctuations are commonly represented by the spherical harmonics C_ℓ. The connection between the harmonic ℓ and k is roughly

$$\ell \simeq k \, \frac{2c}{H_0 \, \Omega_{\mathrm{m}}^{0.4}} \tag{2}$$

for a flat Universe. For $\Omega_{\mathrm{m}} = 0.3$ the 2dFGRS range $0.02 < k < 0.15 \, h \, \mathrm{Mpc}^{-1}$ corresponds approximately to $200 < \ell < 1500$, which is well covered by the recent CMB experiments.

A well-known problem in estimating cosmological parameters is the degeneracy of parameters, and the choice of free parameters. Here we assume a flat Universe (i.e. zero curvature), and no tensor component in the CMB (for discussion of the degeneracy with respect to these parameters see E02). We consider five free parameters: the matter density parameter Ω_{m}, the linear-theory amplitude of the mass fluctuations $\sigma_{8\mathrm{m}}$, the present-epoch linear biasing parameter $b(L_s, z = 0)$ (for the survey effective luminosity $L_s \simeq 1.9 L_*$), the Hubble constant $h \equiv H_0/(100 \, \mathrm{km \, s^{-1}})$, and the baryon density parameter $\omega_{\mathrm{b}} \equiv \Omega_{\mathrm{b}} h^2$. As we are mainly interested in combinations of $\sigma_{8\mathrm{m}}$, b and Ω_{m}, we shall marginalize over the remaining parameters. We also check the robustness of the results to some 'extra parameters', the optical depth τ due to reionization and the primordial spectral index n.

The latest CMB measurements from Boomerang (Netterfield et al. 2001, de Bernardis et al. 2002), Maxima (Lee et al. 2001; Stomper et al. 2001) and DASI (Halverson et al. 2002; Pryke et al. 2002) suggest three acoustic peaks. Parameter fitting to a Λ-CDM model indicates consistency between the different experiments, and a best-fit Universe with zero curvature, and an initial spectrum with spectral index $n \simeq 1$ (e.g. Wang et al. 2001, E02 and references therein). Unlike the earlier Boomerang and Maxima results, the new data also show that the baryon contribution is consistent with the Big Bang Nucleosynthesis value $\omega_{\mathrm{b}} \simeq$

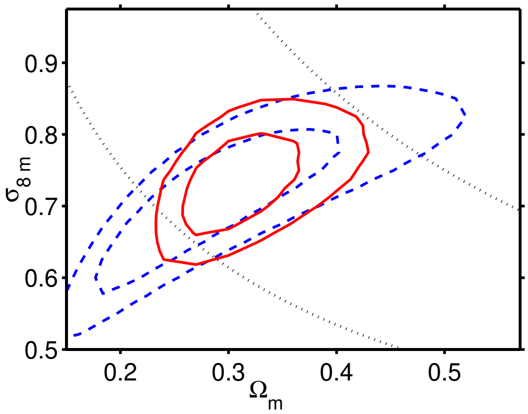

Fig. 2. The likelihood function of CMB alone (dashed lines) in terms of the mass fluctuation amplitude $\sigma_{8\mathrm{m}}$ and the present epoch Ω_{m}. The marginalization over the Hubble constant is done with a Gaussian centred at $h = 0.7$ and standard deviation of 0.07. Other parameters are held fixed $(n = 1, \omega_{\mathrm{b}} = 0.02, \tau = 0.0)$. The contours are for (two-parameter) 68 per cent and 95 per cent confidence intervals. The solid lines show the contours (68 per cent and 95 per cent) for the joint 2dFGRS+CMB analysis, after marginalization over h, $b(L_s, 0)$ and ω_{b}. Other parameters are held fixed $(n = 1, \tau = 0.0)$. Note that the contours of 2dFGRS+CMB are much tighter than when using CMB alone. Two recent extreme cluster abundance determinations are overlayed as the upper dotted line (Pierpaoli et al. 2001) and the lower dotted line (Viana et al. 2002). From Lahav et al. (2001).

0.02 (O'Meara et al. 2001). We have used a compilation of COBE, Boomerang, Maxima and DASI data, after marginalization over calibration errors (Bridle et al. 2001b).

When combining 2dFGRS and CMB data the parameterization for the log-likelihoods is then:

$$\begin{aligned} \ln \mathcal{L}_{\mathrm{tot}} &= \ln \mathcal{L}_{\mathrm{2dFGRS}}[\Omega_{\mathrm{m}}, h, \omega_{\mathrm{b}}, \sigma_{8\mathrm{m}}, b(L_s, 0)] \\ &\quad + \ln \mathcal{L}_{\mathrm{CMB}}[\Omega_{\mathrm{m}}, h, \omega_{\mathrm{b}}, \sigma_{8\mathrm{m}}], \end{aligned} \tag{3}$$

where $\mathcal{L}_{\mathrm{2dFGRS}}$ and $\mathcal{L}_{\mathrm{CMB}}$ are the likelihood functions for 2dFGRS and the CMB.

The 2dFGRS likelihood function takes into account the redshift-space distortions, an epoch-independent galaxy clustering biasing scheme, and the redshift evolution of $\Omega_{\mathrm{m}}(z)$. Other parameters are held fixed $(n = 1, \tau = 0)$.

Fig. 2. (solid lines) shows the 2dFGRS+CMB likelihood as a function of $(\Omega_{\mathrm{m}}, \sigma_{8\mathrm{m}})$, after marginalization over $h, b(L_s, 0)$ and ω_{b}. The peak of the distribution is consistent with the result for the CMB alone (shown by the dashed lines in Fig. 2.), but we see that the contours are tighter due to the addition of the 2dFGRS data. Further marginalization over Ω_{m} gives $\sigma_{8\mathrm{m}} = 0.73 \pm 0.05$.

To study the biasing parameter we marginalize the 2dFGRS likelihood over $h, \omega_{\rm b}$, $\sigma_{8\rm m}$ and $\Omega_{\rm m}$ (with fixed parameters are held fixed $n = 1, \tau = 0$) and we get $b(L_s, 0) = 1.10 \pm 0.08$ (1-sigma).

To translate the biasing parameter from L_s to e.g. L_* galaxies one can either assume (somewhat ad-hoc) no luminosity segregation on large scales, or divide by the factor 1.14 (Norberg et al. 2001a) that applies on small scales. We also tested sensitivity to the spectral index n and the optical depth τ. Overall, our results can be described by the following formula:

$$b(L_*, z = 0) = (0.96 \pm 0.08)\ \exp[-\tau + 0.5(n-1)]. \qquad (4)$$

4. Comparison with other measurements

4.1. Other estimates of 2dFGRS amplitude of fluctuations

An independent measurement from 2dFGRS comes from redshift-space distortions on scales $\lesssim 10\,h^{-1}\,{\rm Mpc}$ (Peacock et al. 2001). This gives $\beta(L_s, z_s) = 0.43 \pm 0.07$. Using the full likelihood function in the $(b, \Omega_{\rm m})$ plane we derive a slightly larger (but consistent) value, $\beta(L_s, z_s) \simeq 0.48 \pm 0.06$.

A study of the bi-spectrum of the 2dFGRS (Verde et al. 2001) on smaller scales ($0.1 < k < 0.5\,h\,{\rm Mpc}^{-1}$) sets constraints on deviations from linear biasing, and it gives a best-fit solution consistent with linear biasing of unity. The agreement with the 2dF+CMB result is impressive, given that the methods used are entirely different. In fact, by matching the two results one can get constraints on e.g. the optical depth $\tau \lesssim 0.2$.

4.2. Comparison with other independent measurements

Our derived values for $\sigma_{8\rm g}^{R}(L_*, z = 0)$ is in accord with with the values derived from the early Sloan Digital Sky Survey (SDSS) by Szalay et al. (2001).

Cluster abundance is a popular method for constraining $\sigma_{8\rm m}$ and $\Omega_{\rm m}$ on scales of $\sim 10\,h^{-1}\,{\rm Mpc}$. Four recent analyses span a wide range of values, but interestingly they are all orthogonal to our CMB and 2dF constraints (Fig. 3). For example, for $\Omega_{\rm m} = 0.3$. Pierpaoli, Scott & White (2001), Seljak (2001), Reiprich & Boehringer (2002), and Viana, Nichol & Liddle (2002) found: $\sigma_{8\rm m} \simeq 1.02; 0.75; 0.68; 0.61$ respectively (with typical errors of 10 per cent). The discrepancy between the different estimates is in part due to differences in the assumed mass-temperature relation. The cluster physics still needs to be better understood before we can conclude which of the above results is more plausible. We see in Fig. 2 that the lower cluster abundance results are actually in good agreement with our value from the 2dFGRS+CMB, $\sigma_{8\rm m} \simeq 0.73 \pm 0.05$.

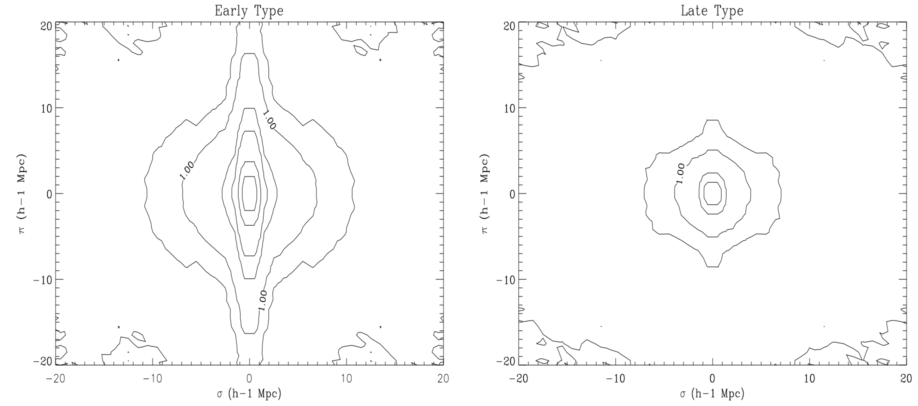

Fig. 3. The two point correlation function $\xi(\sigma, \pi)$ plotted for passively (left) and actively (right) star-forming galaxies. The contour levels are 15,10,5,3,1 (labelled),0.5,0. From Madgwick & Lahav (2001) and Madgwick, Hawkins et al. (in preparation).

The measurements of weak gravitational lensing (cosmic shear) are sensitive to the amplitude of the matter power spectrum on mildly non-linear scales. For example, for $\Omega_{\rm m} = 0.3$ Bacon et al. (2002) and Van Waerbeke et al. (2002) find $\sigma_{8\rm m} \simeq 0.97$ (with errors of about 20 per cent). These estimates are higher than the $\sigma_{8\rm m}$ value that we obtain from 2dFGRS+CMB, but note the large error bars in this recently developed method.

5. Clustering per spectral type

Although biasing was commonly neglected until the early 1980s, it has become evident that on scales $\lesssim 10\,h^{-1}$ Mpc different galaxy populations exhibit different clustering amplitudes, the so-called morphology-density relation (e.g. Dressler 1980; Hermit et al. 1996). Biasing on small scales is also predicted in the simulations of hierarchical clustering from CDM initial conditions (e.g. Benson et al. 2000). It is important therefore to pay attention to the scale on which biasing operates.

Madgwick et al. (2002) have utilized the method of Principal Component Analysis (PCA) to compress each galaxy spectrum into one quantity, $\eta \approx 0.5\, pc_1 + pc_2$. Qualitatively, η is an indicator of the current star formation in a galaxy. This allows us to divide the 2dFGRS into η-types, and to study e.g. luminosity functions and clustering per type.

Norberg et al. (2002) found that for L_* galaxies, the real space correlation function amplitude of η early-type galaxies is $\sim 50\%$ higher than that of late-type galaxies. Fig 3 (from Madgwick & Lahav 2001) shows the redshift space correlation function in terms of the line-of-sight and perpendicular to the line-of-sight separation $\xi(\sigma, \pi)$. In this plot we show the correlation function calculated from the most passively ('red') and actively ('blue') star-forming galaxies. It can be seen that the clustering properties of the two samples are quite distinct on scales $\lesssim 10\,h^{-1}$ Mpc. The 'red' galaxies display a prominent 'finger-of-god' effect and also have a higher overall normalization than the 'blue' galaxies. This is a manifestation of the well-known morphology-density relation. This diagram allows us to determine the combination of the mass density and biasing parameter $\beta = \Omega_m^{0.6}/b$ (e.g. Peacock et al. 2001; Hawkins et al., in preparation).

6. Discussion

We have combined the latest 2dFGRS and CMB data. The first main result of this joint analysis is the normalization of the mass fluctuations, $\sigma_{8\mathrm{m}} = 0.73 \pm 0.05$. This normalization is lower than the COBE normalization and previous estimates from cluster abundance, but it is actually in agreement with recently revised cluster abundance normalization. The results from cosmic shear are still somewhat higher, but with larger error bars.

The second result is for the biasing parameter for optically-selected L_s galaxies, $b(L_s, 0) = 1.10 \pm 0.08$, which is consistent with no biasing ('light traces mass') on scales of tens of Mpc. When translated to L_* via a correction valid for small scales we get a slight anti-bias, $b(L_*, 0) \simeq 0.96$. Our result of linear biasing of unity on scales ($\gtrsim 10\,h^{-1}$ Mpc) is actually in agreement with predictions of simulations (e.g. Blanton et al. 2000 Benson et al. 2000; Somerville et al. 2001). It was also demonstrated by Fry (1996) that even if biasing was larger than unity at high redshift, it would converge towards unity at late epochs. Yet on scales $\lesssim 10\,h^{-1}$ Mpc different galaxy populations have different clustering amplitudes.

It may well be that in the future the cosmological parameters will be fixed by CMB, SNe etc. Then, for fixed reasonable cosmological parameters, one can use redshift surveys to study biasing, evolution, etc. The above analysis is a modest illustration of this approach. Future work along these lines will include exploring non-linear biasing models (e.g. Dekel & Lahav 1999; Sigad, Branchini & Dekel 2001; Verde et al. 2001) per spectral type or colour (Madgwick et al 2001; Norberg et al. 2002; Madgwick, Hawkins et al., in preparation; Zehavi et al. 2001) and the detailed variation of other galaxy properties with local mass density.

Overall, the results from 2dFGRS fit well into the 'concordance' model which has emerged from various cosmological data sets. The Λ-CDM model with comparable amounts of dark matter and dark energy is rather esoteric, but it is remarkable that different measurements converge to the 'concordance model' with parameters:

- $\Omega_k \approx 0$,
- $\Omega_m = 1 - \Omega_\Lambda \approx 0.3$,
- $\Omega_b h^2 \approx 0.02$,
- $h \approx 0.7$
- the age of the Universe $t_0 \approx 14$ Gyr,
- the spectral index $n \approx 1$,
- $\sigma_{8\mathrm{m}} \approx 0.75$.

  Perhaps the least accurate estimates on that list are for Ω_m and $\sigma_{8\mathrm{m}}$.

While phenomenologically the Λ-CDM model has been successful in fitting a wide range of cosmological data, there are some open questions:

- Both components of the model, Λ and CDM, have not been directly measured. Are they 'real' entities or just 'epicycles' ?
- Why is $\Omega_m \sim \Omega_\Lambda$ at the present-epoch ? Do we need to introduce a new physics or invoke the Anthropic Principle to explain it ?
- There are still open problems in Λ-CDM on the small scales e.g. galaxy profiles and satellites.
- The age of the Universe is uncomfortably close to some estimates for the age of the Globular Clusters, when their epoch of formation is also taken into account (Gnedin, Lahav & Rees 2001).
- Could other (yet unknown) models fit the data equally well ?
- Where does the field go from here ? Would the activity focus on refinement of the cosmological parameters within Λ-CDM, or on introducing entirely new paradigms ?

These issues will no doubt be revisited soon with larger and more accurate data sets. We will soon be able to map the fluctuations with scale and epoch, and to analyze jointly redshift surveys (e.g. 2dF, SDSS) and CMB (e.g. MAP, Planck) data. These high quality data sets will allow us to study a wider range of models and parameters.

ACKNOWLEDGMENTS

I thank Sarah Bridle, Darren Madgwick and the 2dFGRS team members for their contribution to the work described here. The 2dF Galaxy Redshift Survey was made possible through the dedicated efforts of the staff of the Anglo-Australian Observatory, both in creating the 2dF instrument and in supporting it on the telescope. I also thank the conference organizers for the hospitality in Tokyo.

References

[1] Bacon D.J., Massey R.J., Refregier A.R., Ellis, R.S., 2002, MNRAS, submitted, astro-ph/0203134

[2] Bahcall N.A., Ostriker J.P., Perlmutter S., Steinhardt P.J., 1999, Science, 284, 148

[3] Benson A.J., Cole S., Frenk C.S., Baugh C.M., Lacey C.G., 2000, MNRAS, 311, 793

[4] Blanton M., Cen R., Ostriker J.P., Strauss M.A., Tegmark M., 2000. ApJ, 531, 1

[5] Bridle S.L., Zehavi I., Dekel A., Lahav O., Hobson M.P., Lasenby A.N., 2001a, MNRAS, 321, 333

[6] Bridle S.L., Crittenden R., Melchiorri A., Hobson M.P., Kneissl R., Lasenby A., 2001b, MNRAS, submitted, astro-ph/0112114

[7] Colless M. & the 2dFGRS team, 2001, MNRAS, 328, 1039

[8] de Bernardis P., et al. 2002, ApJ, 564, 559

[9] Dekel A., Lahav O., 1999, ApJ, 520, 24

[10] Dressler A., 1980, ApJ, 236, 351

[11] Efstathiou G. & the 2dFGRS team, 2002, MNRAS, 330, 29

[12] Elgaroy O., Gramann M., Lahav O., 2002, MNRAS, 333, 93

[13] Freedman W.L., et al., 2001, ApJ, 553, 47

[14] Fry J.N., 1996, ApJ, 461, L65

[15] Gnedin, O., Lahav, O., Rees, M.J., 2001, M.J., astro-ph/0108034

[16] Halverson N.W., et al. 2002, ApJ, 568, 38

[17] Hermit S., Santiago B.X., Lahav O., Strauss M.A., Davis M., Dressler A., Huchra J.P., 1996, MNRAS, 283, 709

[18] Lahav O., Bridle S.L., & the 2dF Team, 2001, MNRAS, in press, astro-ph/0112162

[19] Lee A.T. et al., 2001, ApJ, 561, L1

[20] Madgwick D.S. & the 2dFGRS team, 2002, MNRAS, 333, 133

[21] Madgwick D.S., Lahav O., 2001, astro-ph/0110220

[22] Netterfield C.B. et al., 2001, ApJ, accepted, astro-ph/0104460

[23] Norberg P. & the 2dFGRS team, 2001a, MNRAS, 328, 64

[24] Norberg P. & the 2dFGRS team, 2002, MNRAS, 332, 827

[25] O'Meara J.M. et al., 2001, 552, 718

[26] Peacock J.A. & the 2dFGRS team, 2001, Nature, 410, 169

[27] Percival W.J. & the 2dFGRS team, 2001, MNRAS, 327, 1297

[28] Pierpaoli E., Scott D., White M., 2001, MNRAS, 325, 77

[29] Pryke C. et al., 2002, ApJ, 568, 46

[30] Reiprich T.H., Boehringer H., 2002, ApJ, 567, 716

[31] Seljak U., 2001, MNRAS, submitted, astro-ph/0111362

[32] Sigad Y., Branchini E., Dekel A., 1999, ApJ, 520, 24

[33] Somerville R., Lemson G., Sigad Y., Dekel A., Colberg J., Kauffmann G., White S.D.M., 2001, MNRAS, 320, 289

[34] Stompor R. et al., 2001, ApJ, 561, L7

[35] Szalay A.S. & the SDSS team, 2001, ApJ, submitted, astro-ph/0107419

[36] Tegmark M., Hamilton A.J.S., Xu Y., 2001, astro-ph/0111575

[37] Van Waerbeke L., et al. 2002, astro-ph/0202503

[38] Verde L. et al. & the 2dFGRS team, MNRAS, accepted, astro-ph/0112161

[39] Viana P.T.P., Nichol R.C., Liddle A.R., 2002, ApJ, 569, L75

[40] Wang X., Tegmark M., Zaldarriaga M., 2001, PRD, accpeted, astro-ph/0105091

[41] Webster M., Bridle S.L., Hobson M.P., Lasenby A.N., Lahav O., Rocha, G., 1998, ApJ Lett, 509, L65

[42] Zehavi I., et al., 2001, ApJ, accepted, astro-ph/0106476