The Universe on Very Large Scales: 
A View from the Las Campanas Redshift Survey

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Abstract. The Las Campanas Redshift Survey (LCRS) is among the first galaxy redshift surveys to sample a reasonably fair volume of the local Universe. On the largest scales ($\gg 100 \ h^{-1} \ Mpc$), the galaxy distribution appears smooth; on relatively small scales ($\lesssim 10 \ h^{-1} \ Mpc$), the LCRS tends to confirm the clustering characteristics observed in previous, shallower surveys. Here, however, we concern ourselves primarily with clustering on scales near the transition to homogeneity ($50 - 200 \ h^{-1} \ Mpc$). We conclude that the general evidence tends to support enhanced clustering on $\sim 100 \ h^{-1} \ Mpc$ scales, but that this result should be confirmed with additional analyses of the LCRS dataset (especially 2D analyses) and with investigations of new and upcoming large-scale surveys covering different regions and/or having different selection effects.

1 Introduction

When the strategy for the Las Campanas Redshift Survey (LCRS; [9]) was first being formulated in the mid-1980’s, the goals were two-fold: first, to sample a fair volume of the local Universe (what are the largest coherent structures? at what point does the Universe start to look smooth?), and, second, to study clustering on large scales ($\xi_{gg}(s)$, void statistics, ...). Therefore, it was decided to survey an unfilled “checkerboard” pattern in both the north and the south galactic caps out to a redshift of $z \sim 0.2$. To facilitate these ends, it was decided to use a 50-fiber multi-object spectrograph (MOS) to obtain the radial velocities. This was circa 1986/87. A few years into the survey (circa 1990/91), the survey strategy evolved into what became its final form: a set of six filled-in slices – three in the north galactic cap, and three in the south. Also during this time frame, the MOS was upgraded to 112-fibers.

The maps that were gradually built up over the course of the survey eventually began to show an intriguing picture – that of a Universe which looked smooth on large scales! Visually, there was little or no evidence in the LCRS slices for high-contrast coherent structures on scales $\gg 100 \ h^{-1} \ Mpc$. Quantitative evidence has tended to support this initial view (e.g., see Fig. 8 of [3] and Fig. 1 of [10]).

At the other extreme, on relatively small scales ($\lesssim 10 \ h^{-1} \ Mpc$), the LCRS has generally confirmed what had been observed in previous, shallower surveys.
But what about scales near the transition to homogeneity (50 – 200 $h^{-1}$ Mpc)? What can the LCRS tell us about clustering on these scales?

2 Results

On very large scales ($\gtrsim 50$ $h^{-1}$ Mpc), it makes sense to think of an individual LCRS slice as a 2-dimensional plane, since the third dimension of slice width does not contribute much to our understanding of clustering on these scales (Fig. 1). Now consider a “toy” Universe composed of osculating spherical voids of diameter 100 $h^{-1}$ Mpc. In such a Universe, an LCRS slice would intersect several voids at various random positions. Clearly, the measured cross-sectional diameters of these intersections will never overestimate the true diameter of the spheres (in this case, 100 $h^{-1}$ Mpc). On average, the diameter of the cross-section of a sphere randomly intersecting a plane is

$$< D_{\text{cross-section}} > = \frac{\pi}{4} D_{\text{sphere}} \approx \frac{3}{4} D_{\text{sphere}}. \quad (1)$$

Thus, in such a “toy” Universe, we would expect that an LCRS slice would typically underestimate the average void diameter by about 1/3. This projection effect in real space is basically the same as the aliasing of power from large- to small-scales in Fourier space. In real-space, however, this effect seems rather more benign and correctable.

With the above discussion in mind, what – if any – clustering do we see on scales of 50 – 200 $h^{-1}$ Mpc?

First, consider a couple visual representations of the LCRS $-12^\circ$ Slice, the most densely and most homogeneously sampled of the six LCRS slices. Looking at a standard velocity-RA plot of this slice (Fig. 2), we may notice that the largest coherent high-contrast structures tend to form the walls of underdense regions (“voids”) 50 – 100 $h^{-1}$ Mpc in diameter. To remove radial and field-to-field selection effects, one can generate a smoothed number-density contrast map (Fig. 3); therein, our initial suspicions are confirmed: high-density ($\delta \rho/\rho > 2.5$) regions tend to surround low-density ($\delta \rho/\rho \lesssim 1$) “voids” with diameters of 50 – 100 $h^{-1}$ Mpc.
Figure 2: The LCRS Slice at $-12^\circ$. Only LCRS galaxies in the official redshift sample and within the absolute magnitude range $-22.5 \leq M_R - 5 \log h < -17.5$ are plotted.

Figure 3: Smoothed density contrast map of the LCRS $-12^\circ$ Slice. Smoothing was performed with a $20 \, h^{-1} \text{Mpc}$-diameter tophat filter. The $xy$-coordinates are in comoving distances.
Second, we note that both the LCRS 2D power spectrum and large-scale (\(> 10 \, h^{-1} \, \text{Mpc}\)) 3D spatial autocorrelation function indicate features of excess clustering on scales \(~ 100 \, h^{-1} \, \text{Mpc}\). We note that the results from the 2D power spectrum show higher statistical significance, since the signal at these scales (see Fig. 1) is essentially 2D; at these scales, some of the signal is washed out in the 3D autocorrelation function analysis.

Third, Doroshkevich et al.’s core-sampling analysis of the LCRS measures the mean free path between 2D sheets and between 1D filaments. Comparing their Fig. 12 with our Fig. 3, it is apparent that their sheet-like structures correspond roughly with regions of smoothed \(\delta \rho/\rho \gtrsim 2.5\); their rich filaments, with regions of smoothed \(1.5 \lesssim \delta \rho/\rho \lesssim 2\). Doroshkevich et al. measure the mean free path between sheets to be \(\approx 80 – 100 \, h^{-1} \, \text{Mpc}\).

Fourth, Einasto et al. give evidence that Abell Clusters in rich superclusters tend to lie within a 3D “chessboard” of gridsize of \(~ 120 \, h^{-1} \, \text{Mpc}\). Einasto and his colleagues are presently performing a similar analysis for LCRS galaxies in rich environments; in fact, our Fig. 3 is from the early stages of that analysis. Results, however, are still pending.

3 Conclusions

There does seem to be something going on in the LCRS at a scale of \(~ 100 \, h^{-1} \, \text{Mpc}\), but this result needs confirmation using other techniques (e.g., a 2D \(\xi_{gg}\)) and using other large surveys covering different regions and/or having different selection effects (e.g., the ESP, 2dF, SDSS, ...).

Acknowledgements. We wish to thank the following for fruitful discussions regarding the topic of this paper: Andrei Doroshkevich, Jaan Einasto, Richard Fong, Yasuhiro Hashimoto, Robert Kirshner, Stephen Landy, Augustus Oemler, and Paul Schechter.

References

[1] Colless M.M., this volume
[2] Doroshkevich A.G., Tucker D.L., Oemler A., Kirshner R.P., Lin H., Shectman S.A., Landy S.D., & Fong R., 1996, MNRAS, 283, 1281
[3] Einasto J., Einasto M., Gottlöber S., et al., 1997, Nature, 385, 139
[4] Einasto J., et al. 1998, in preparation
[5] Landy S.D., Shectman S.A., Lin H., Kirshner R.P., Oemler A., & Tucker D., 1996, ApJL 456, 1
[6] Lin H., Kirshner R.P., Shectman S.A., Landy S.D., Oemler A., Tucker D.L., & Schechter P.L., 1996a, ApJ, 464, 60
[7] Lin H., Kirshner R.P., Shectman S.A., Landy S.D., Oemler A., Tucker D.L., & Schechter P.L., 1996b, ApJ, 471, 617
[8] Loveday J., & Pier J., this volume
[9] Shectman S.A., Landy S.D., Oemler A., Tucker D.L., Lin H., Kirshner R.P., & Schechter P.L., 1996, 470, 172
[10] Tucker D.L., Oemler A., Kirshner R.P., et al., 1997, MNRAS, 285, 5.
[11] Vettolani G., Zucca E., Zamorani G, et al., 1997, A&A, 325, 954