LARGE-SCALE STRUCTURE AS SEEN FROM QSO ABSORPTION-LINE SYSTEMS

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We study clustering on very large scales — from several tens to hundreds of co-moving Mpc — using an extensive catalog of heavy-element QSO absorption-line systems. We find significant evidence that C IV absorbers are clustered on comoving scales of 100 h\(^{-1}\) Mpc (\(q_0 = 0.5\)) and less. The superclustering is present even at high redshift (\(z \sim 3\)); furthermore, it does not appear that the superclustering scale (comoving) has changed significantly since then. Our estimate of that scale increases to 240 h\(^{-1}\) Mpc if \(q_0 = 0.1\), which is larger than the largest scales of clustering seen at the present epoch. This may be indicative of a larger value of \(q_0\), and hence \(\Omega_0\). We identify 7 high-redshift supercluster candidates, with 2 at redshift \(z \sim 2.8\). The evolution of the correlation function on 50 h\(^{-1}\) Mpc scales is consistent with that expected in cosmologies with \(\Omega_0 =\) ranging from 0.1 to 1. Finally, we find no evidence for clustering on scales greater than 100 h\(^{-1}\) Mpc (\(q_0 = 0.5\)) or 240 h\(^{-1}\) Mpc (\(q_0 = 0.1\)).

It has been recognized for some time now that QSO absorption line systems are particularly effective probes of large-scale structure in the universe. This is because the absorbers trace matter lying on the QSO line of sight, which can extend over a sizable redshift interval out to high redshifts. Thus, the absorbers trace both the large-scale structure and its evolution in time, since the clustering pattern can be examined as a function of redshift out to \(z \sim 4\). The evolution of large-scale structure is of great interest, since, in the gravitational instability picture, it depends sensitively on \(\Omega_0\).

Here we study clustering by computing line-of-sight correlations of C IV absorption line systems, using a new and extensive catalog of absorbers. (A more complete version of this work has appeared elsewhere.) This catalog contains data on all QSO heavy-element absorption lines in the literature. It is an updated version of the York et al. (1991) catalog but is more than twice the size, with over 2200 absorbers listed over 500 QSOs, and is the largest sample of heavy-element absorbers compiled to date.

Figure 1 shows the C IV line-of-sight correlation function, \(\xi_{aa}\), as a function of absorber comoving separation, \(\Delta r\), for the entire sample of absorbers. The results are shown for both a \(q_0 = 0.5\) (left panel, 25 h\(^{-1}\) Mpc bins) and a \(q_0 = 0.1\) (right panel, 60 h\(^{-1}\) Mpc bins) cosmology. The vertical error bars are required for \(q_0 = 0.1\) because, at high redshift, a larger comoving separation \(\Delta r\) arises from a fixed redshift interval \(\Delta z\).
through the data points are 1 σ errors in the estimator for ξ_{aa}, which differ from the 1 σ region of scatter (dashed line, calculated by Monte Carlo simulations) around the no–clustering null hypothesis.

Remarkably, there appears to be significant clustering in the first four bins of Figure 1: The positive correlation seen in the first four bins of Figure 1 has a significance of 5.0 σ. Therefore, there is significant evidence of clustering of matter traced by C iv absorbers on scales up to 100 h⁻¹ Mpc (q₀ = 0.5) or 240 h⁻¹ Mpc (q₀ = 0.1). There is no evidence from Figure 1 for clustering on comoving scales greater than these.

We have investigated the evolution of the superclustering by dividing the absorber sample into three approximately equal redshift sub–samples; namely, low (1.2 < z < 2.0), medium (2.0 < z < 2.8), and high (2.8 < z < 4.5) redshift. We find that the significant superclustering seen in Figure 1 is present in all three redshift sub–samples, so that the superclustering is present even at redshift z ≳ 3. Furthermore, it does not appear that the superclustering scale, in comoving coordinates, has changed significantly since then.

We have examined the clustering signal more closely and find that a large portion comes from 7 QSO lines of sight that have groups of 4 or more C iv absorbers within a 100 h⁻¹ Mpc interval (q₀ = 0.5). (From Monte Carlo simulations, we expect only 2.7 ± 1.5 QSOs with such groups.) We have found two potential superclusters, at redshift z ~ 2.8, among these groups.

The superclustering is indicative of generic large–scale clustering in the universe, out to high redshift z ≳ 3, on a scale frozen in comoving coordinates that is — if q₀ = 0.5 — similar to the size of the voids and walls in galaxy redshift surveys of the local universe. It also appears consistent with the through the data points are 1 σ errors in the estimator for ξ_{aa}, which differ from the 1 σ region of scatter (dashed line, calculated by Monte Carlo simulations) around the no–clustering null hypothesis.

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general finding that galaxies are clustered in a regular pattern on very large scales, although we have not confirmed that there is quasi-periodic clustering with power peaked at $\sim 128 \, h^{-1} \text{Mpc}$.

Our estimate of the superclustering scale increases to $240 \, h^{-1} \text{Mpc}$ if $q_0 = 0.1$ (see Figure 1), which is larger than the largest scales of clustering known at present. If the structures traced by C IV absorbers are of the same nature as those seen locally in galaxy redshift surveys, the superclustering scale should have a value closer to $100 \, h^{-1} \text{Mpc}$. This may be indicative of a larger value of $q_0$, and hence $\Omega_0$.

We find that the evolution of the correlation function on $50 \, h^{-1} \text{Mpc}$ scales is consistent with that expected in cosmologies with density parameter ranging from $\Omega_0 = 0.1$ to 1.

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