Small Scale Structure of Cosmic Voids

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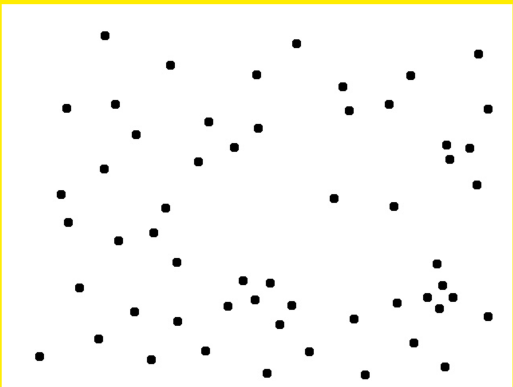
Abstract

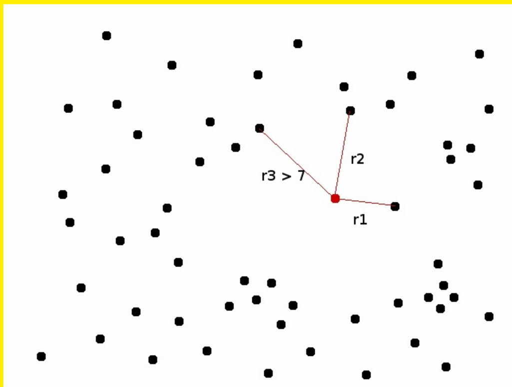
Using VoidFinder (Hoyle & Vogeley 2002, 2004) on Sloan Digital Sky Survey, Data Release 7, we have found 1054 large scale voids in this survey filling 62% of the volume. The largest voids are over 30 Mpc in radius, with a 15 Mpc median. We have identified over 8,046 void galaxies with Mr < -20.09, and 79,947 galaxies with m < 17.6, approximately 6-7% of all galaxies in the respective samples. We find the voids to be elliptical in shape with no particular preference to orientation along the line of sight. We also find void galaxies to be less correlated than their wall galaxy counterparts.

How Do We Find Voids?

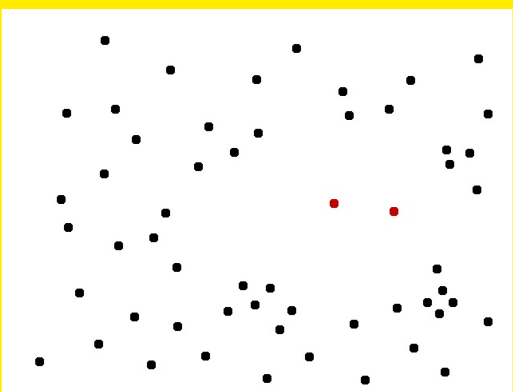
VoidFinder is a galaxy based void finding algorithm that uses redshift data to find statistically significant cosmic voids. VoidFinder is based on the El-Ad & Piran (1997) method and uses a nearest neighbor algorithm on a volume limited galaxy catalog for void finding, and works as follows.

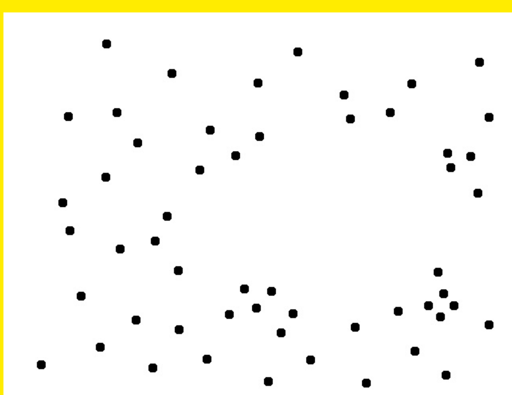
VoidFinder is applied to volume limited galaxy samples. The galaxies are classified as wall or field galaxies. A field galaxy is an isolated galaxy that may live in a void region. Wall galaxies lie in the cosmic filaments and clusters. The distance parameter d for determining whether a galaxy is a wall or field galaxy is based on the third nearest neighbor distance (d3).



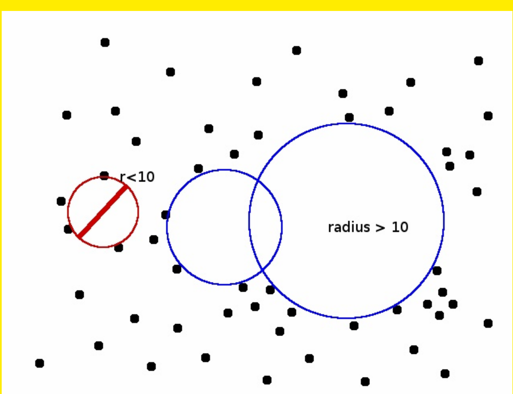


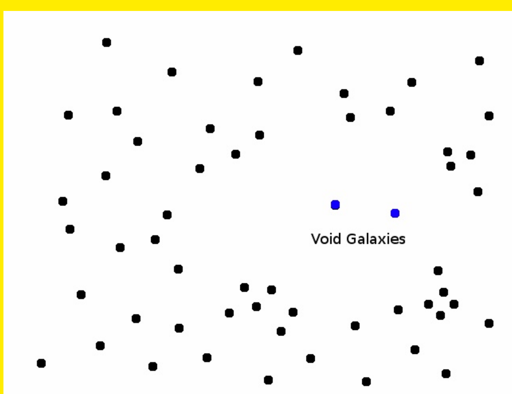
All galaxies fitting this criteria are identified as field galaxies and removed from the sample.

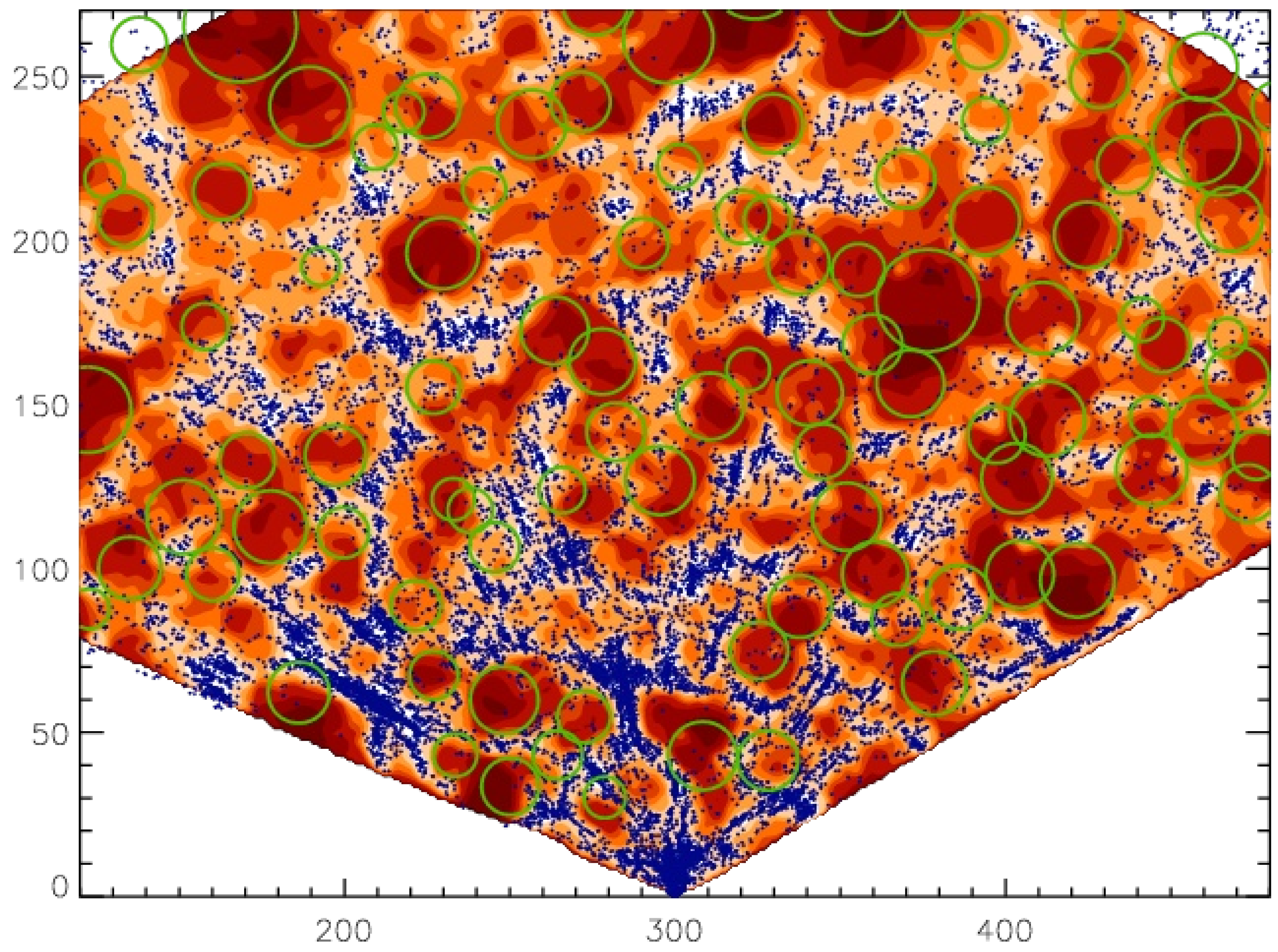




The volume is gridded up and empty spheres are allowed to grow within the volume. A minimum radius of 10 Mpc is required for a region to be considered a void, and two spheres overlapping by more than 10% of its volume are merged to form single non-spherical void regions. Finally, the field galaxies are placed back into the volume. Any galaxy falling within a void region is considerd a void galaxy

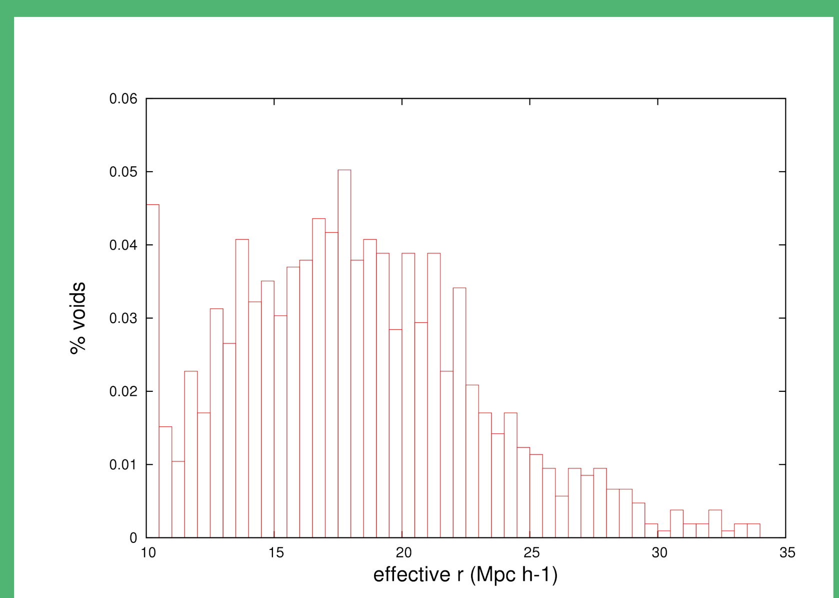


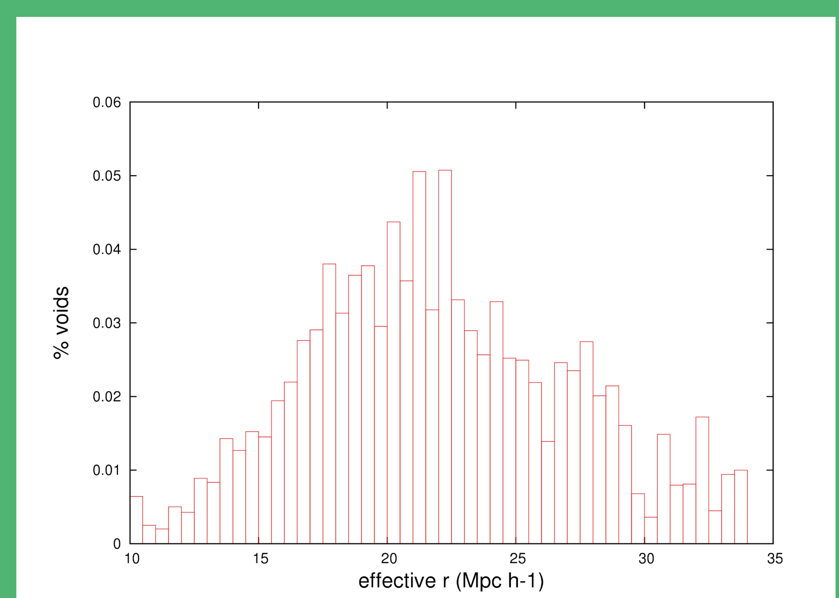




How Big Are The Voids? 100 Million Light-Years Across

We identify 1,054 voids in SDSS DR7. The largest voids are 30 Mpc in effective radii, where the volume of the void region is equal to the volume of the sphere with radius r_{eff}, and the median void effective radius is 17 Mpc. The voids cover 62% of the volume in the sample, and contain 7% of the volume limited galaxies. We have also identified 79,947 void galaxies with SDSS spectra that lie within the voids in the r < 17.6 magnitude limited catalog.



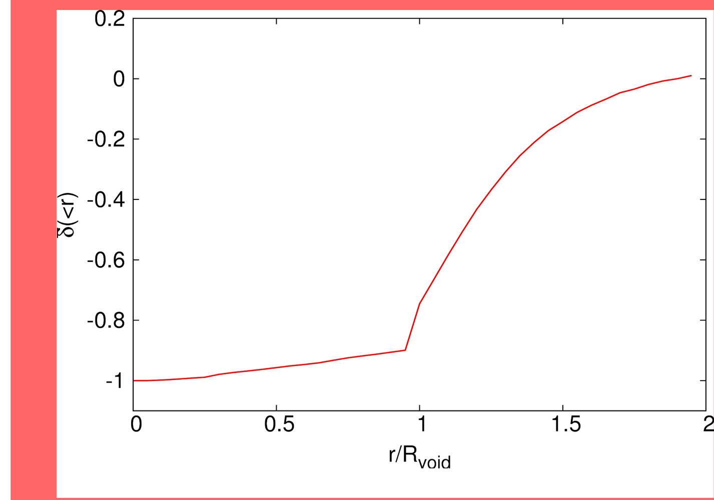


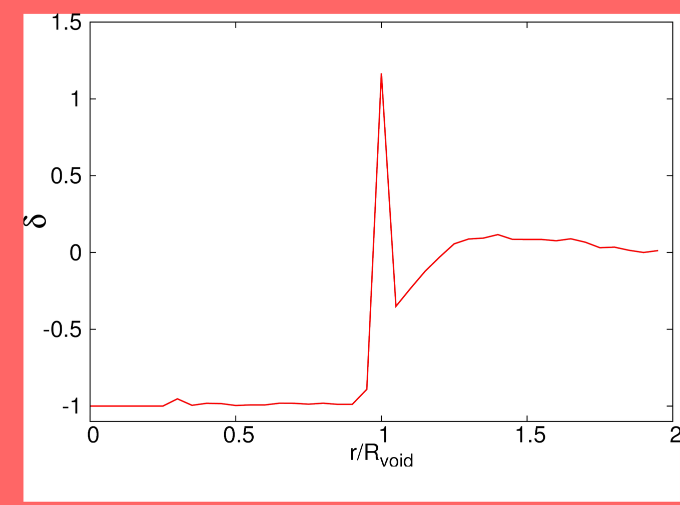
The figure on the left shows a histogram of reff of the voids by the number of voids found. The figure on the right shows a histogram of reff of the voids by the volume enclosed by those voids. While most voids are smaller in size, the medium sized voids dominate the void volume.

We did similar tests of VoidFinder on various LCDM mock galaxy catalogs and found similar results. Using a similar geometry cut to SDSS DR7, we found 1,006 voids and 6,228 void galaxies inhabiting 66% of the volume. Using a cube geometry with volume slightly larger than SDSS DR7, we found 1,246 and 7,881 void galaxies inhabiting 69% of the volume. The discrepancies arise from the halo occupancy models used by various mock galaxy simulations. Void finding can be a good measure of the success of various HOD models on large scales.

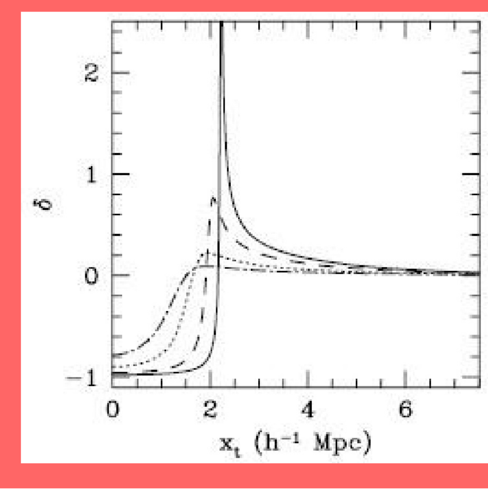
"AntiGravity" Made The Voids

The radial density profiles of the cosmic voids show that voids are significantly underdense, having less than 10% of the average density all the way out to the very edge of the voids. The figure on the left shows the stacked radial density profile of the voids. The density is calculated from the volume enclosed to the given effective radius of the void. The figure on the right shows a similar stacked radial density profile of the voids. However, the density is now calculated as the density of a spherical annulus emanating from the center of the given void region. It can be seen that the walls of the voids are quite sharp, quickly growing from 10% of the average density to 100%, and the voids are very well defined in terms of their density contrast with the outside Universe. It is clear then that these voids are distinct features of the Universe.





A comparison with linear gravitation theory from Sheth & van de Weygaert (2004) shows the same "bucket shaped" radial density profile.



Is There Structure Within Voids?

We find void galaxies to be less clustered than normal galaxies. By assuming a power law distribution to the two point correlation function, we find that void galaxies cluster on a scale of 3.5 Mpc while normal galaxies cluster on a scale of 7.8 Mpc. This is in accordance to theory and simulation results from Abbas & Sheth (2007) where they find that galaxies in less dense regions of the Universe are less clustered than their wall galaxy counterparts.