Structure of Cosmic Voids

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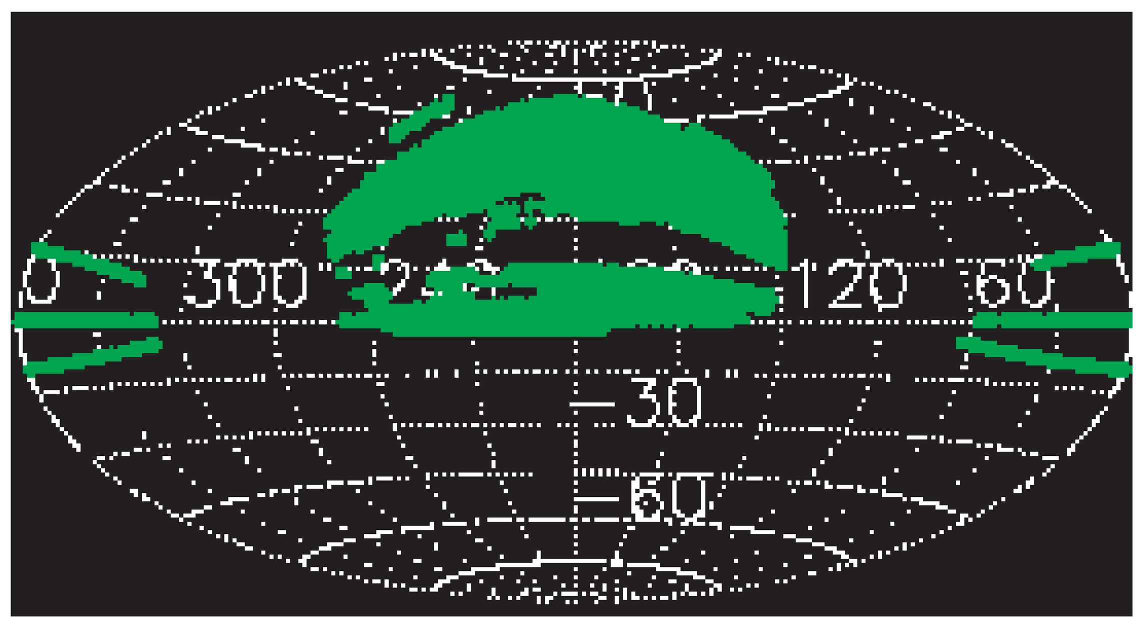
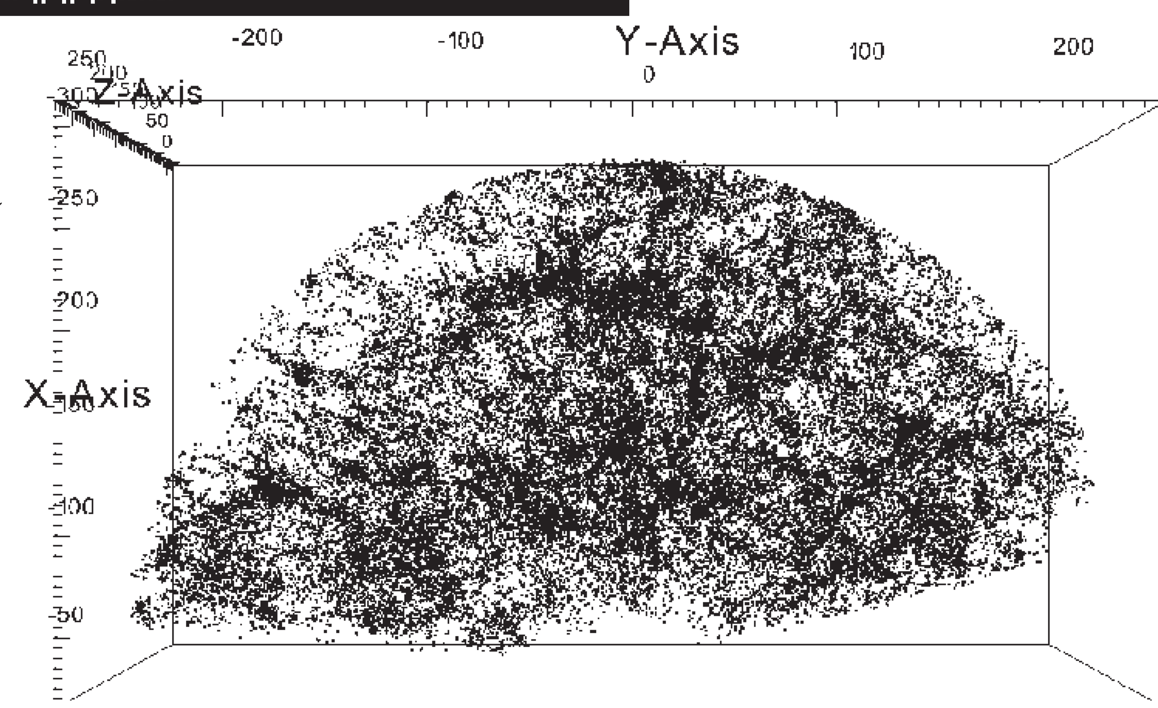
Summary

We present a new catalog of 526 voids identified from volume-limited samples of the SDSS using the algorithm described in Hoyle & Vogeley (2002). We test the sensitivity of void properties to details of this algorithm and quantify the clustering of galaxies that lie within these voids. The internal structure of voids reflects both their growth by gravitational instability and the details of how light traces mass in the lowest-density environments of the universe. We find that voids traced by ~L_* galaxies fill 50% of the volume of space. Measurement of their radial density profiles reveals the signature of void growth by gravitational instability: nearly flat density profiles with $\delta\rho/\rho \sim -0.9$ in their central regions and a sharp rise at the walls of the voids. This behavior indicates that voids are dynamically distinct elements of large-scale structure. This largest to-date catalog of voids is publicly available as a value-added catalog to supplement the SDSS data.



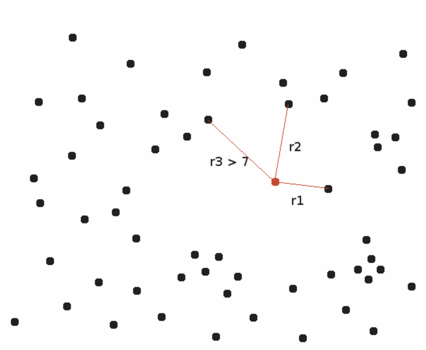
Sky distribution of completed spectroscopy in SDSS Data Release 5
5740 square degrees
674,749 galaxies
Spectra: 3800-9200 Å
http://www.sdss.org

Volume limited catalog
Subsample of SDSS data
Abs. mag. limit:
-20 + 5log(h)
z_{max}=0.107
61,084 galaxies

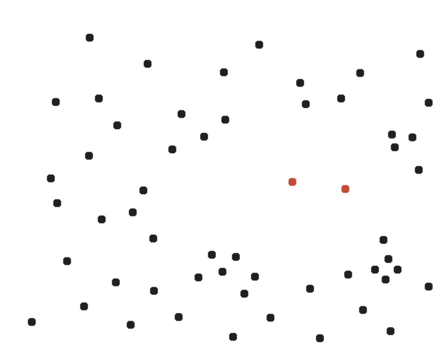


How VoidFinder Works

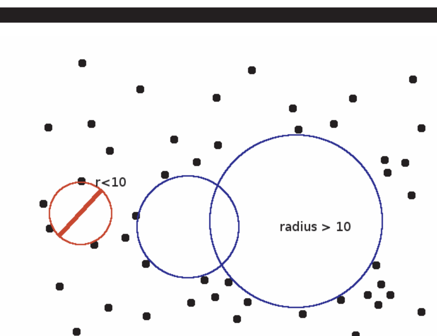
VoidFinder (Hoyle & Vogeley 2002) is used to locate void regions and void galaxies. The method is illustrated below:



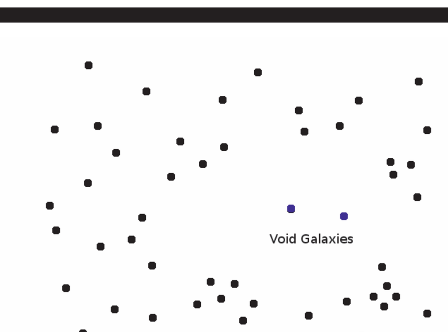
Distances to 3rd nearest neighbor, d3, is found for each galaxy



If d3NN > 7 h^{-1} Mpc, mark as potential void galaxy and remove



Maximal spheres (r>10 h^{-1} Mpc) grown to encapsulate void regions.

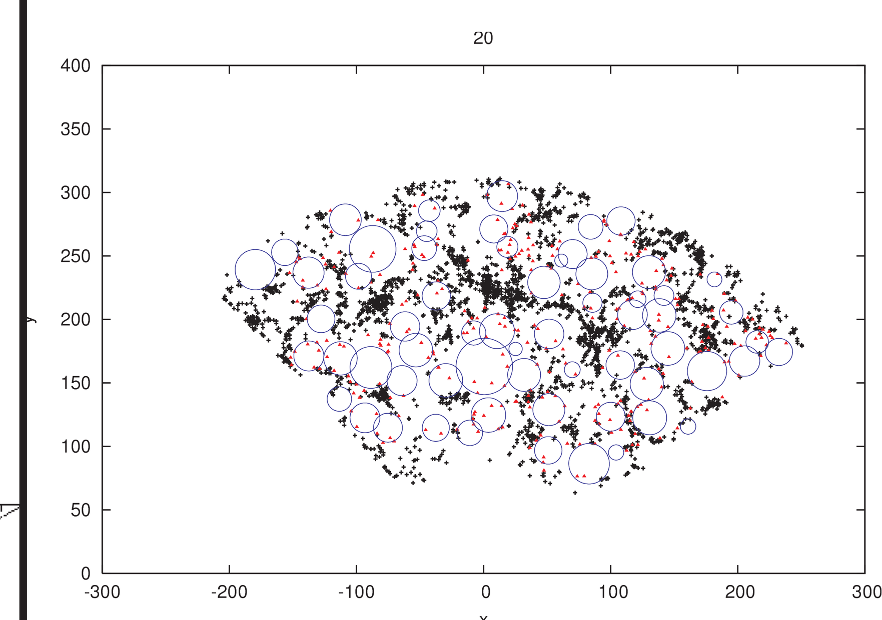


Potential void galaxies placed back in. If potential void galaxy lies within a void region, it is a void galaxy.

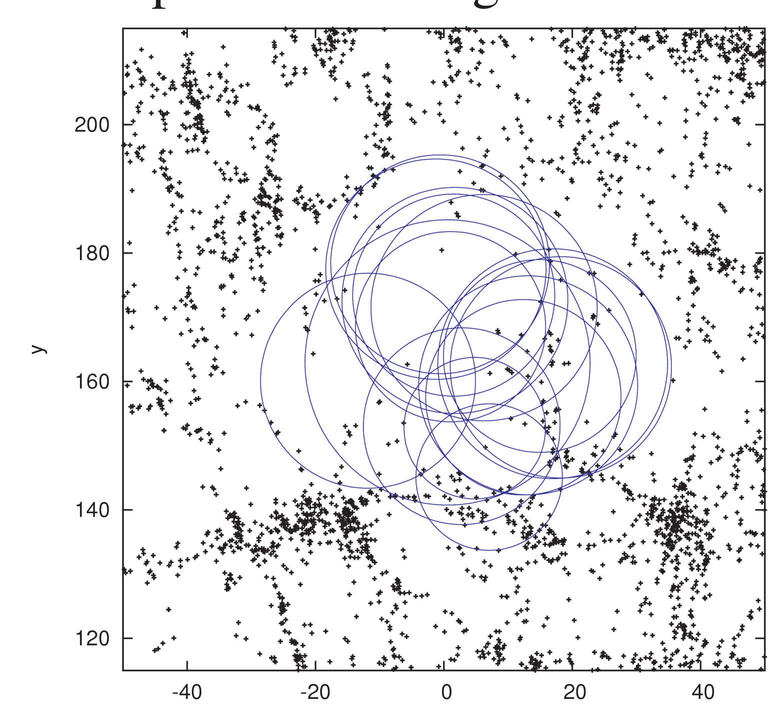
Results of VoidFinder

VoidFinder finds 526 statistically significant voids in the SDSS Data Release 5 sample. These voids make up 50% of the total volume in the sample, and contain 20% of the galaxies. The sample used for identifying voids was chosen with an absolute magnitude cut of -20+5log(h) (approximately Milky Way luminosity), and comoving distance 100 < d < 300 h^{-1} Mpc, which corresponds to a redshift of z = 0.107.

A copy of the void catalog is available at:
http://www.physics.drexel.edu/~pan/voidcatalog/



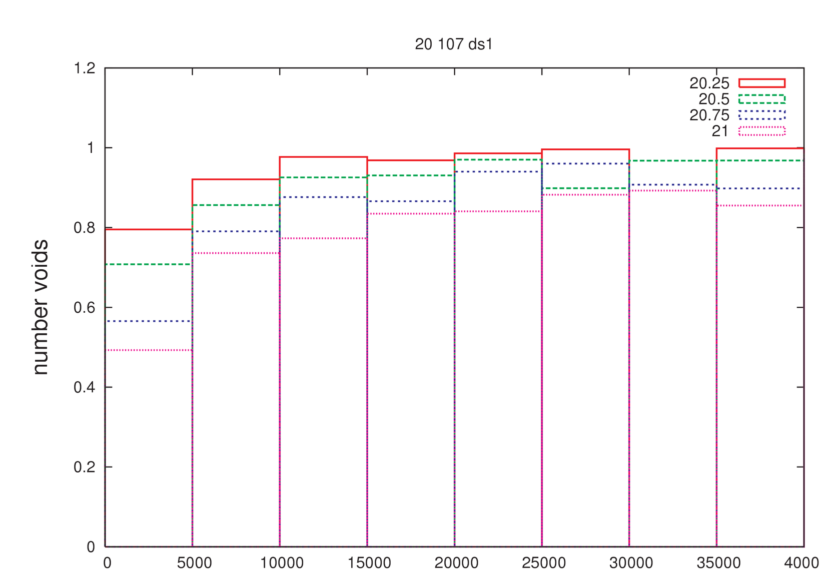
20 Mpc thick slice centered on the largest maximal sphere in the void sample. Void galaxies are red and wall galaxies are black in the slice of the volume limited sample, and intersections with all maximal spheres are displayed.

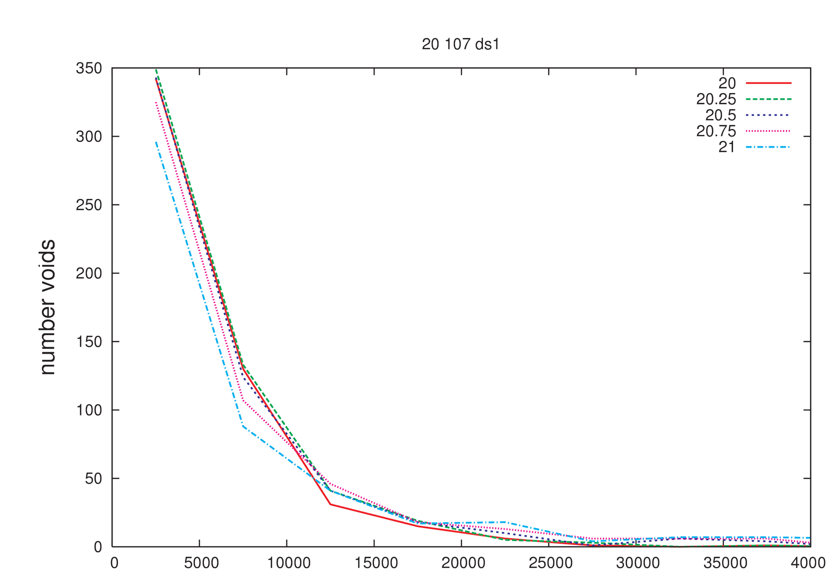


Zoom-in on the largest void region found by VoidFinder in SDSS DR 5. This 10 Mpc thick slice shows the magnitude limited sample along with maximal spheres found with VoidFinder that make up a single void region.

Void Sizes

The number and volume of voids found in the various samples are consistent for variations of the absolute magnitude limit from -20 to -21. Discrepancies occur only for the smallest voids. This is expected because a lower sample density creates small voids that are not statistically significant.

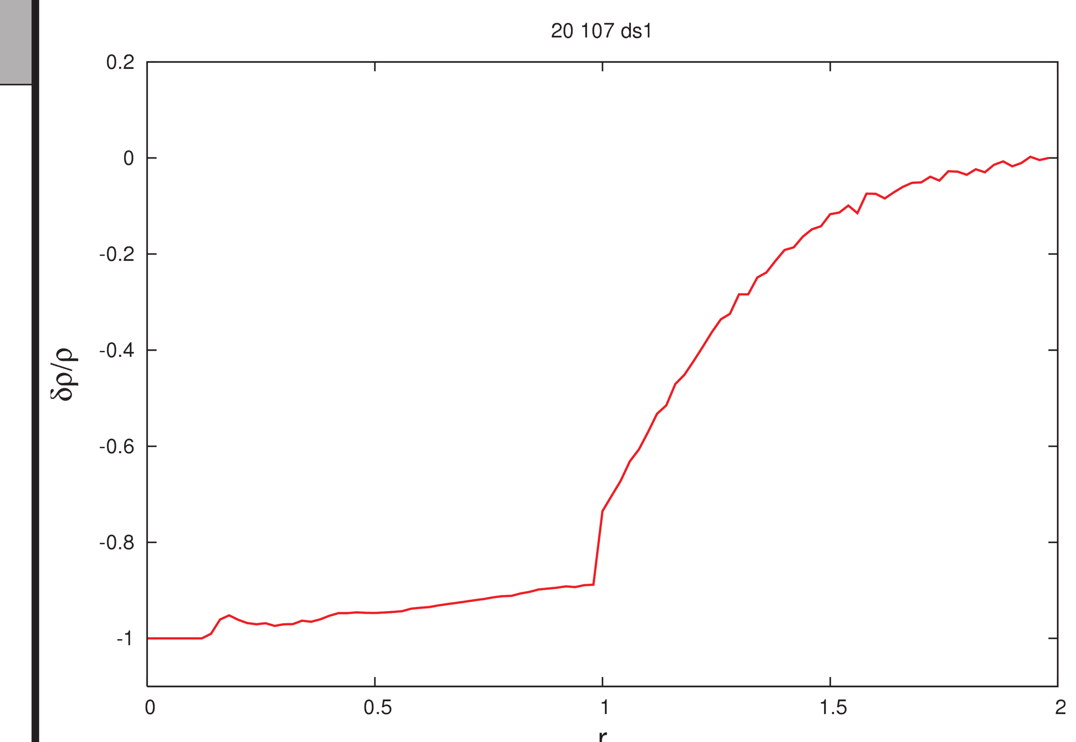




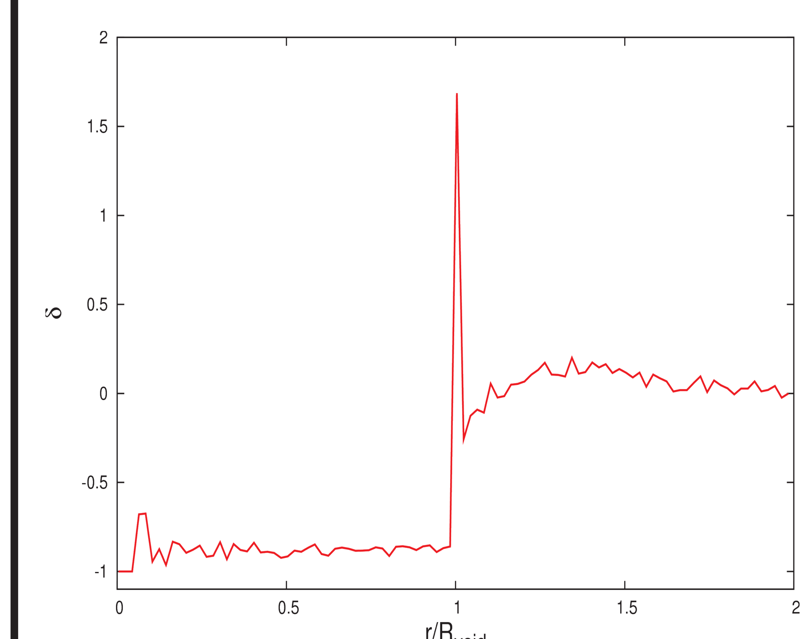
Left: Overlap fractions of various samples with the base void sample.
Right: Number of voids found in each sample as a function of the volume of the void.

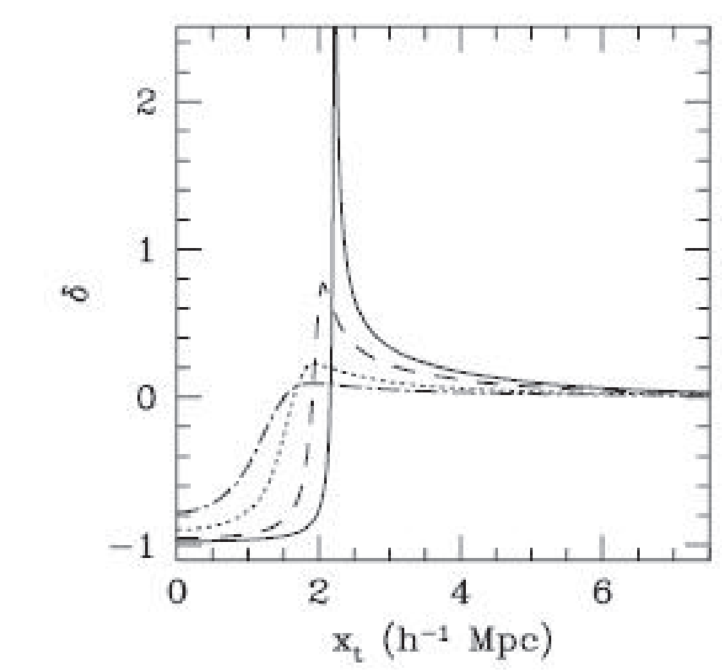
Radial Density Profiles

The radial density profiles of the voids found in SDSS are consistent with the predictions of void growth by gravitational instability. By looking at the radial density profiles, in both enclosed volumes as well as spherical shells growing from the centers of the voids, it can be seen that the voids are significantly underdense compared to their immediate environment. The bucket shaped radial density profile is in agreement with linear gravitation theory as predicted by Sheth and van de Weygaert (2004).



δρ/ρ (enclosed) starting from the center of of the maximal sphere of each void region. The results of 526 voids are averaged and stacked together. It can be seen that the voids are significantly underdense at the center, and that the edge is fairly sharp as wall galaxies begin to be enclosed.





Left: Observed density of spherical shells as a function of void radius out from the center of void regions averaged over the 526 voids found.
Right: Density of spherical shells as predicted by Sheth and van de Weygaert (2004).

Substructure in Voids

After determining the set of voids and void galaxies, we statistically characterize structure within the voids. We quantify this smaller scale structure using the two-point correlation function, which appears consistent with the overall structure as identified in the Millenium Run simulation by Springel et al. (2005). In progress is a morphological analysis of structures in voids using ShapeFinder statistics (Sahni et al. 1998).

References

Hoyle, F., Vogeley, M. S., 2002, ApJ, 566, 641
Sahni, V. et al., 1998, ApJ, 495, L5
Sheth, R.K., van de Weygaert, R., 2004, MNRAS, 350, 517
Springel et al., 2005, Nature, 435, 629
The Fifth Data Release of the Sloan Digital Sky Survey, ApJ, 172, 634

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