Mass Function of Void Galaxies

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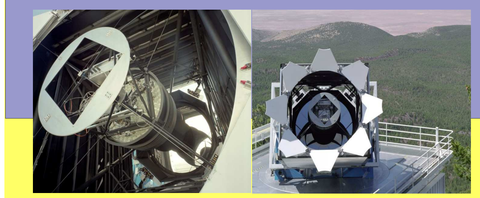
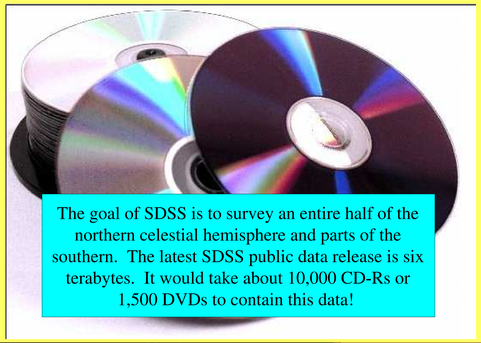
Observations of galaxies in the known universe have found a homogeneous distribution on large enough scales, and a patently non-homogeneous distribution on local scales. Galaxies tend to exist in large interconnected clusters of high density. Areas of especially low density exist in the "voids" between these clusters, so that the distribution of density has a sponge-like nature. Galaxies found within these especially low density regions, so called "Void" galaxies, have received much attention recently. Of most relevance, recent Drexel graduate Dr. Randall Rojas has found that Void galaxies differ from non-Void galaxies in significant ways (Rojas et al. 2004). Statistically, Void galaxies are seen to be bluer, fainter, have higher specific star formation rates, and tend more often to be of spiral type than non-Void galaxies. The purpose of this research is to compare theoretical models of void mass functions with observational mass function estimation using data from the second SDSS data release. Further work in this area might demonstrate how the differing cosmologies result in differing galaxy properties between Voids and non-Voids. The response of galaxy formation to differing cosmological environments will advance the theory of galaxy formation by offering model constraints and testability. More accurate models of galaxy formation will, in turn, offer further constraints for cosmological theory.

I. Data

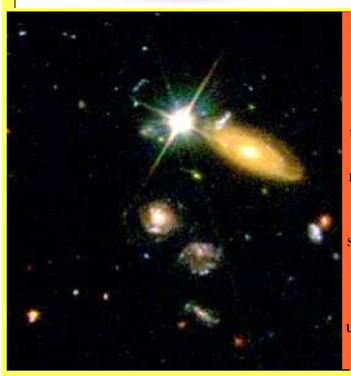
Sloan Digital Sky Survey

The Sloan Digital Sky Survey (SDSS) is an ambitious multi-institutional project designed to obtain a large database of galaxies and distant quasars.





The goal of SDSS is to survey an entire half of the northern celestial hemisphere and parts of the southern. The latest SDSS public data release is six terabytes. It would take about 10,000 CD-Rs or 1,500 DVDs to contain this data!



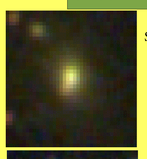
Most galaxies exist in clusters, that is, they have many neighbors. Such galaxies make up the vast majority of the SDSS data release of galaxies.

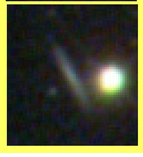
From this vast sample, we can gain a broader spectroscopic and photometric understanding of the "average" galaxy.

Some galaxies exist in isolated, near void regions of space. These "void" galaxies are relatively rare, thus necessitating the use of a vast survey such as SDSS to study them.

Such loner galaxies are the subject of our research.

SDSS: Hubble Telescope's Hard-Working Cousin

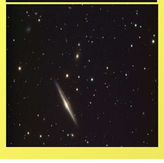




SDSS produces both photometric and spectroscopic data for each targeted galaxy.

For nearby galaxies,SDSS can produce dramatically clear pictures (such as those at right) which are great for public consumption.

Most images, though, are fuzzy and won't make good magazine covers. Yet they still provide a superb amount of data for scientific analysis.



II. Theory

What's the big deal about void galaxies?

Voids are bluer than normal galaxies, implying a differing star type distribution.

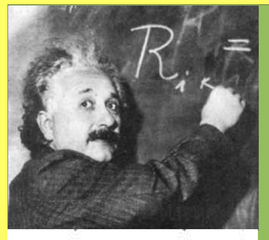
Voids are dimmer than other galaxies, implying lower mass and size.

Voids have higher specific star formation rates, meaning they produce more stars per mass than the average galaxy.

Of the two main morphological types, elliptical and spiral, voids tend more often to be spiral galaxies.

Spiral type

Elliptical type



$$M = \frac{4\pi}{3}\rho_0 R^3,$$

$$\nu \equiv \frac{\delta_c/D(z) - \mu}{\sigma}$$

$$f(M,z)dM = -\frac{dF}{dM}dM = \sqrt{\frac{2}{\pi}}\exp\left(-\frac{\nu^2}{2}\right)\frac{d\nu}{dM}dM$$

$$n(M,z)dM = f(M,z)\frac{\rho_0}{M}(1+\delta_{v,z}) = \sqrt{\frac{2}{\pi}}\exp\left(-\frac{\nu^2}{2}\right)(1+\delta_{v,z})\frac{\rho_0}{M}\frac{d\nu}{dM}dM$$

Cosmology and Void Galaxies

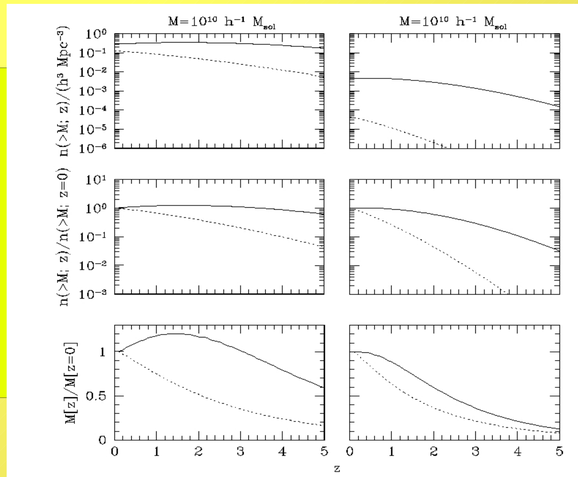
Cosmology is the the theory that deals with the very large scales in our universe. Based on Einstein's revolutionary General Theory of Relativity, Cosmology relates how the presence of matter curves space and time.

Since void galaxies exist in regions with relatively low matter content, we might expect that the cosmological properties of these regions differ from that of non-void regions. The fact that void galaxies have been found to differ from non-void galaxies seems to support this.

Goldberg and Vogeley (2004) use an important theorem in general relativity (Birkhoff, 1923) that posits that given a large enough spherical shell, one can ignore everything outside of such a shell and treat the interior as an independent universe with different cosmological properties. Using this theorem, they create a model for the growth of structure in void regions.

It is the goal of this paper to test that model against real void galaxies from a sample culled from the Sloan Digital Sky Survey.

III. Results

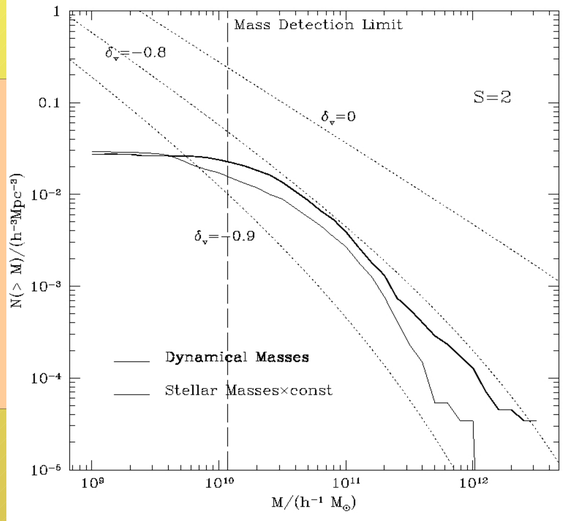


The Goldberg & Vogeley model predicts a mass function (dotted lines) for varying redshift (z).

Redshift measures how "old" a photon received in the telescope is.

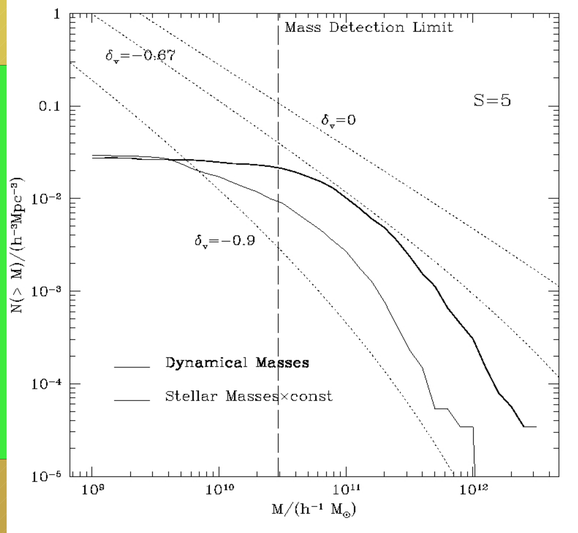
Thus effectively it is a measure over time.

The solid lines represent what we would expect for the average galaxy.



From the largest sample of void galaxies yet compiled, we cull spectroscopic information and use well founded mass estimations to create a void mass function and compare it to the theoretical model.

The exact extent of dark matter is unknown, so we calculate our mass function using a realistic range of scale factors.



What is to the left of the vertical line is the observational limit of the SDSS survey. We are interested in comparing the part of the graph to the right of this line. The dark line is the empirical find, the bottom two dotted lines are theoretical lines for voids. The top most dotted line represents an average galaxy region.
We find good agreement between the empirical and theoretical mass functions for void regions.

References:

Goldberg D.M, **Jones T.**, Hoyle, F. Rojas R. R., Vogeley M. S., Blanton M.R., "The Mass Function of Void Galaxies in the SDSS Data Release 2", in preparation

Goldberg, D.M. & Vogeley, M.S., 2004, ApJ, in press

Birkhoff, G.D. 1923, "Relativisity and Modern Physics," (Cambridge, Mass: Harvard University Press).