SHAWN HUANG
ANNIE PANG
SHREYAS RAO
ANIKA RAWAT
ALEX WEI

INTERSTELLAR

A Comparison of Statistical Distributions of SDSS Galaxies to a Randomly Generated Patch of the Universe

COSMOS UC Irvine
California State Summer School for Math and Science

ABSTRACT

Are galaxies within the Universe uniformly distributed today?

Since the size of the Universe makes it impossible to fully map out, this question becomes crucial to investigate. If it was uniform, it would be easier to simulate many parts of the Universe for further research. The Big Bang Theory assumes that matter is perfectly uniformly distributed [4]. It is possible to use statistical analysis to characterize parts of the Universe to challenge this assumption and to determine the structure of it. While various densities of galaxies within sections of the Universe that space telescopes have observed are different, when looking at data from the Sloan Digital Sky Survey (SDSS), the variance of the galaxy number density was found to be 2.2 higher than that of a randomly generated set of galaxies. Such patterns suggest that the Universe is not uniform; instead, it tends to cluster.

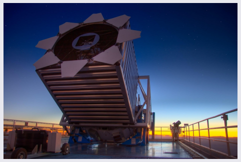

Figure 1: Sloan Telescope, sdss.org

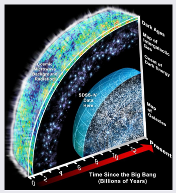

Figure 2: Evolution of Galaxies in the Universe, Forbes.com

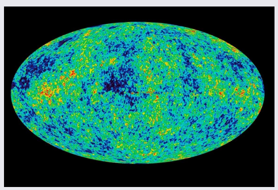

Figure 3: Cosmic Microwave Background, Image Taken by Wilkinson Microwave Anisotropy Probe

BACKGROUND

- In the Early Universe, which was uniformly distributed in density, fluctuations caused large-scale structure and can be seen in the Cosmic Microwave Background (Figure 3)[4].
- Variance, the comparison of a set of data to the statistical mean, can be used to determine levels of randomness and uniformity.
- Uniform data have a lower variance than non-uniform data.
- The Poisson process can be used to calculate numbers of galaxies in frustums with increasing radii.
- Variance in galaxy number density can be calculated through the following formula:

$$\sigma^2_D = \sigma^2_V / V^2$$

METHOD

The variance in the density of galaxies can be calculated through the Monte Carlo method by generating multiple random samples from SDSS data set to approximate a solution. Using Python to generate these samples through random frustums (Figure 4) and to calculate the density of galaxies within them, it is possible to measure the variance of the densities and compare it to the generated data. Figures 6 and 7 compare clustered and random data to provide a baseline for the results.

3.37450309904282335 1e+02	1.26613408965406404 3e+00	8.83722826838493347 2e-02
3.51144156956160316 0e+02	1.27351974880228491 2e+00	6.74991831183433532 7e-02
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1.66465902749311567 3e+01	1.26528735570691131 0e+00	5.02229519188404083 3e-02

Table 1: NASA SLOAN Atlas Digital Sky Survey Right Ascension, Declination, Redshift (example set)

DATA

Figures 4, 6-9: Generated While Conducting Research

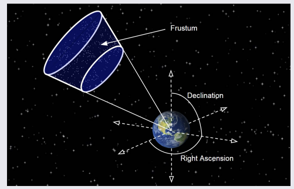

Figure 4: Representation of Our Unique Code Process of Generating Random Frustums

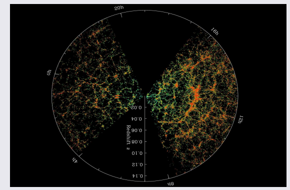

Figure 5: NASA SLOAN Atlas Digital Sky Survey, sdss.org

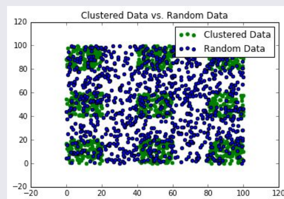

Figure 6: Clustered Data vs. Random Data in a Coordinate Plot (An extreme scenario)

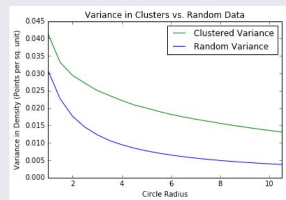

Figure 7: Variance in Density (Points per Degrees^2) vs. Circle Radius (Degrees)

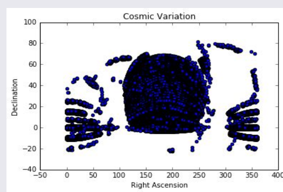

Figure 8: Galaxies from Sloan Digital Sky Survey in 2D: Declination (Degrees) vs. Right Ascension (Degrees)

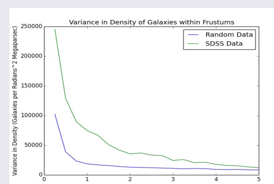

Figure 9: Graph of Variation in Density of Galaxies Within Random Frustums of Increasing Radii for SDSS and Randomly Generated Data. Variance (Radians^2 Megaparsec) vs. Frustum Base Radius (Degrees)

CONCLUSION

In the simpler model, the clustered data has a significantly higher variance in density than the random data (Figures 6 and 7). The variance of galaxy density within the SDSS data is also greater than the random set by a factor of, on average, 2.2 (Figure 9). This suggests that the distribution of galaxies in the Universe is not uniform. Instead, the spatial arrangement of the cosmic web is clustered.

The structure of these clusters gives insight on how the environment of the Early Universe has evolved. Research suggests that the quantum fluctuations in the Early Universe combined with inflation and gravity, have formed the large-scale cosmic structures seen today [4].

FUTURE DIRECTIONS

Utilizing massive sky surveys from groundbreaking telescopes such as the Large Synoptic Survey Telescope (LSST)[3], our research can be applied to more expansive data to recognize more clustering patterns in the Universe. Performing simulations to understand galaxy arrangements over a function of time and vast spatial scales will help scientists learn more about how key cosmic structures evolve and form. The study of galaxy clustering as a function of redshift, including the effects of gravitational forces over cosmic time, is a central topic for further research.

ACKNOWLEDGEMENTS

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