A simple model for cosmic Shock waves and the large scale structure of the

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Large Scale Structure

- Galaxies tend to form in clumps
- There are many clusters, super clusters and voids
- Filaments connect clusters, and surround voids
Clusters

- Our local cluster: ~ 30 galaxies
- Super-clusters can contain thousands of galaxies
Modeling the formation of clusters

- Shock waves caused by dynamical effects move through the universe
- Galaxies are likely to cluster where shock waves meet
Model and Observation
Model: single wave

- Model the structure of clusters by adding circular waves
Model: single wave
Model: Multiple waves

• We can realistically model the clusters by adding multiple waves
Model: Multiple waves
Model: Multiple waves

• 300x300 matrix representing a grid of space
• 100 waves (each with a different origin) added for each point
• uniform or gaussian distribution of random numbers used to position each wave
Results: Random distributions

Gaussian random number distribution

Uniform random number distribution
Results: Adding the waves

Gaussian random number distribution

Uniform random number distribution
Results: Picking the peaks

Gaussian random number distribution

Uniform random number distribution
Results: Voronoi diagram
Model: the control parameter

- Wavelength of the waves was used as the control parameter

- Large wavelengths result in highly ordered structures, with large voids

- Small wavelengths result in little visible symmetry, and no large voids
Model: the control parameter

- Similar for gaussian distributed random numbers, but not as pronounced.
Conclusion

• A highly complex structure can be modeled by adding few simple waves

• Gaussian distribution: voids always present, filament structure not so obvious

• Uniform distribution: large voids only obvious for large wavelengths, clustering highly dependent on wavelength
References

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