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Developing Scholars Program

Dark Halos: The Windowed Power Spectrum

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Abstract:

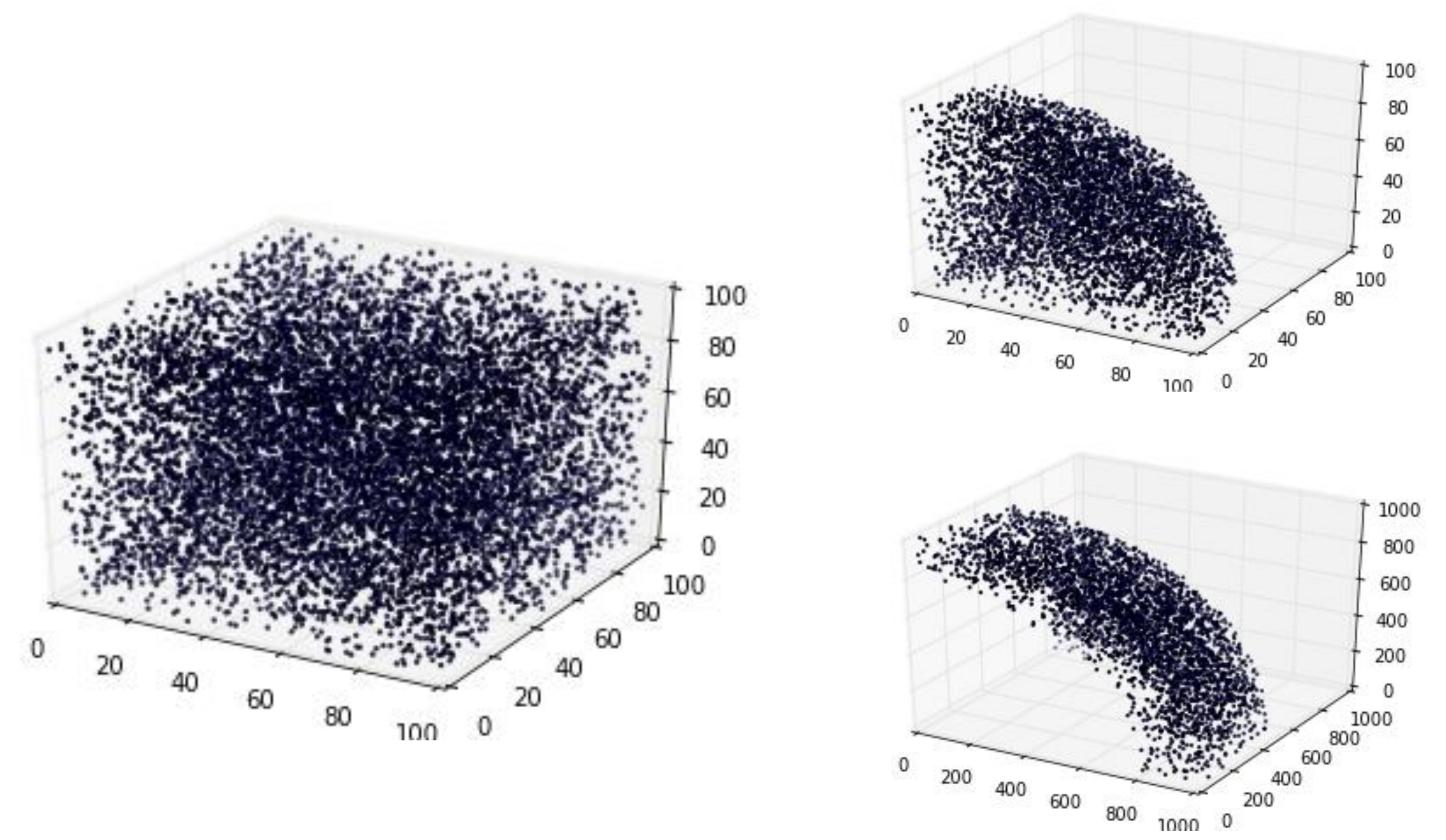
Today, it is believed that approximately 80 percent of the matter that comprises the universe takes the form of dark matter--a theorized substance that interacts with “normal” baryonic matter mostly through gravitational force. Through gravitation, dark matter creates potential wells that determine the motion of stars inside galaxies and galaxies inside galaxy clusters. Dark matter accumulates and forms roughly spherical structures called “dark halos”. Most galaxies and groups of galaxies are located inside such halos. Visible matter tends to cluster inside these halos because of the higher accumulation of dark matter and deeper gravitational wells. The power spectrum is obtained from a Fourier transform of the “galaxy correlation function” which is simply the degree of clustering over a certain scale. The power spectrum is useful for the analysis of clustering and density fluctuations as it gives the variation power as a function of the spatial scale--thereby enumerating the magnitude of small fluctuations in density that through gravity, are amplified and give rise to large-scale universal structure. Theoretical predictions are easy to make for distributions of galaxies in a cube. Real observations, however, have a more complicated geometry. There are usually upper and lower cuts in the distance, and the angular mask is very sophisticated. The purpose of this project is to calculate and determine how the power spectrum of halos is influenced by the implementation of a window function representative of limited visibility. To be able to use our theoretical predictions, we should be able to predict what happens to the power spectrum when an observational mask is applied to galaxies. Using the data from the Dark Sky Simulations Collaboration, we will develop numeric codes for applying the effect to the data. We can then observe how the statistical properties of halos vary based on the observational window applied and how they are related to the properties of their progenitor dark matter.

Background:

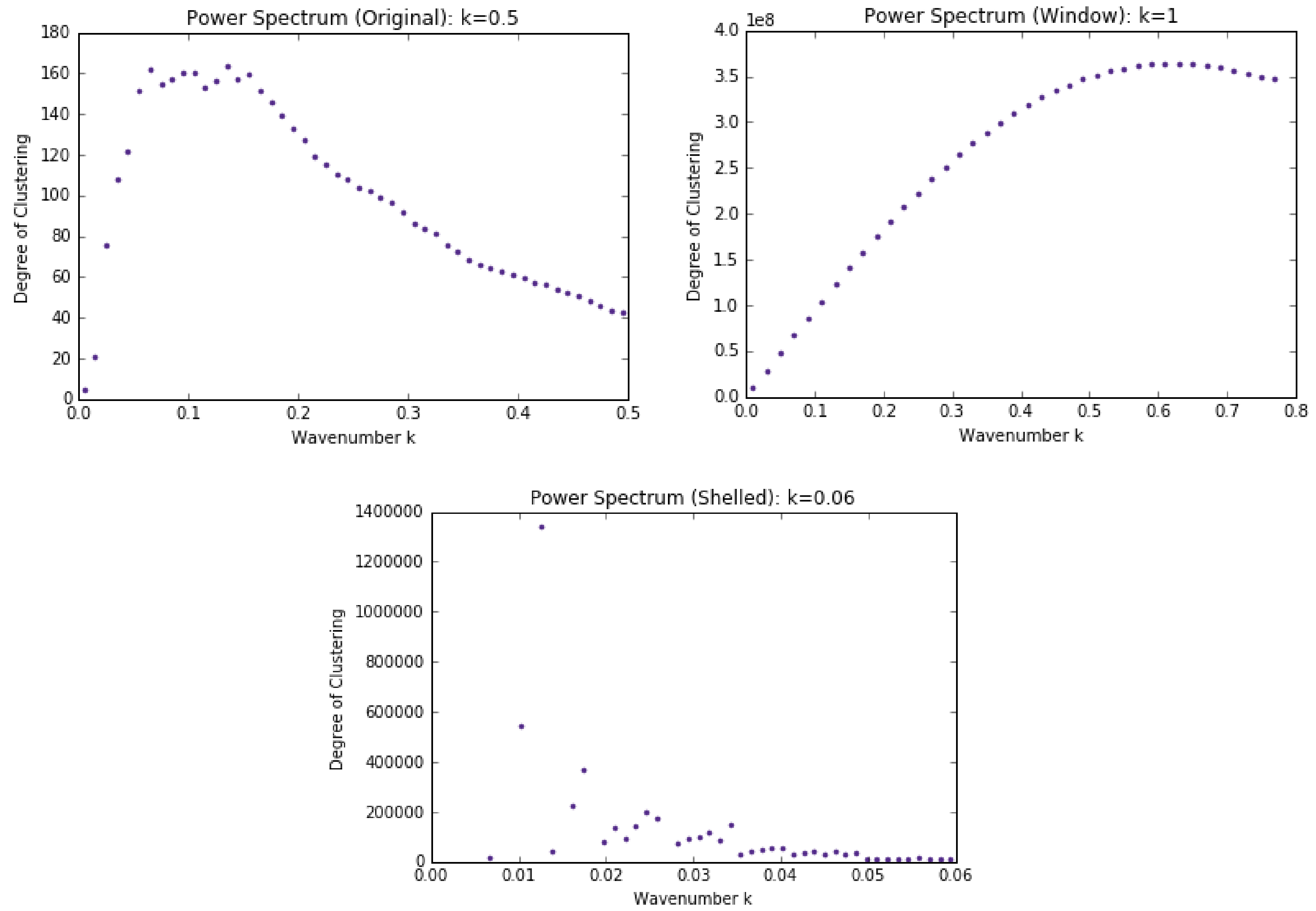
There is significant evidence to the existence of a dark matter separate from luminous matter. Stellar/galactic motion and structure cannot be explained alone by baryonic matter and its gravitational interactions. Dark Sky Simulations numerically evolve millions of dark matter particles based on laws of gravity and known rate of the expansion of the Universe to develop multiple N-body simulations meant to model the structure and dynamics of the Universe on a massive scale.

Results:

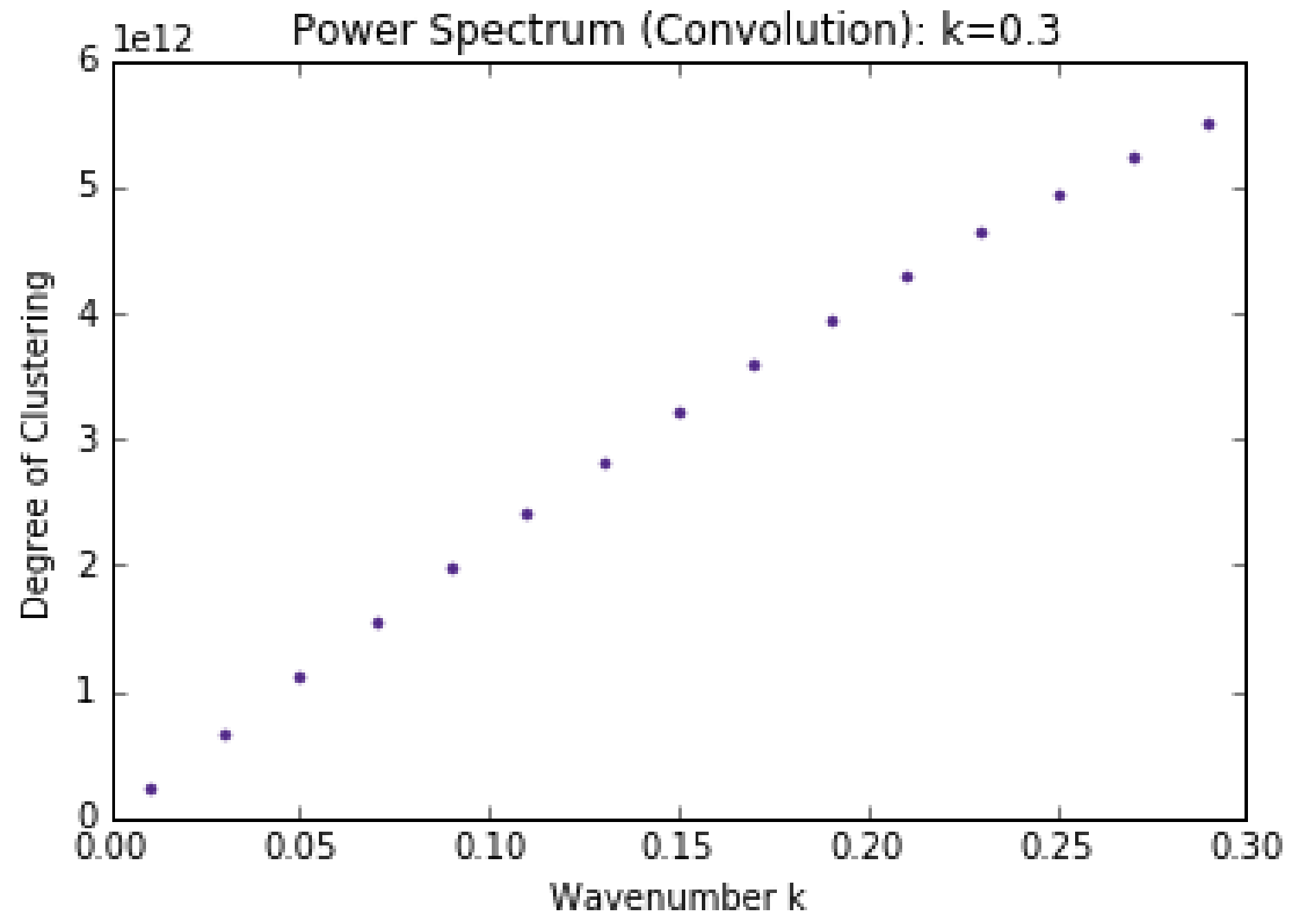
Original Cube vs. Windowed Cube



Power Spectrum: Original, Window, Shelled



Power Spectrum: Convolution



Background (continued):

These models can be used to identify the positions of dark matter halos and study their formation history and statistical properties. Once we understand how dark matter behaves on large scales, that information can be used to interpret the data from ground-based and space-based experiments (galaxy surveys) that are mapping out the distribution of millions of galaxies in the Universe.

Methods:

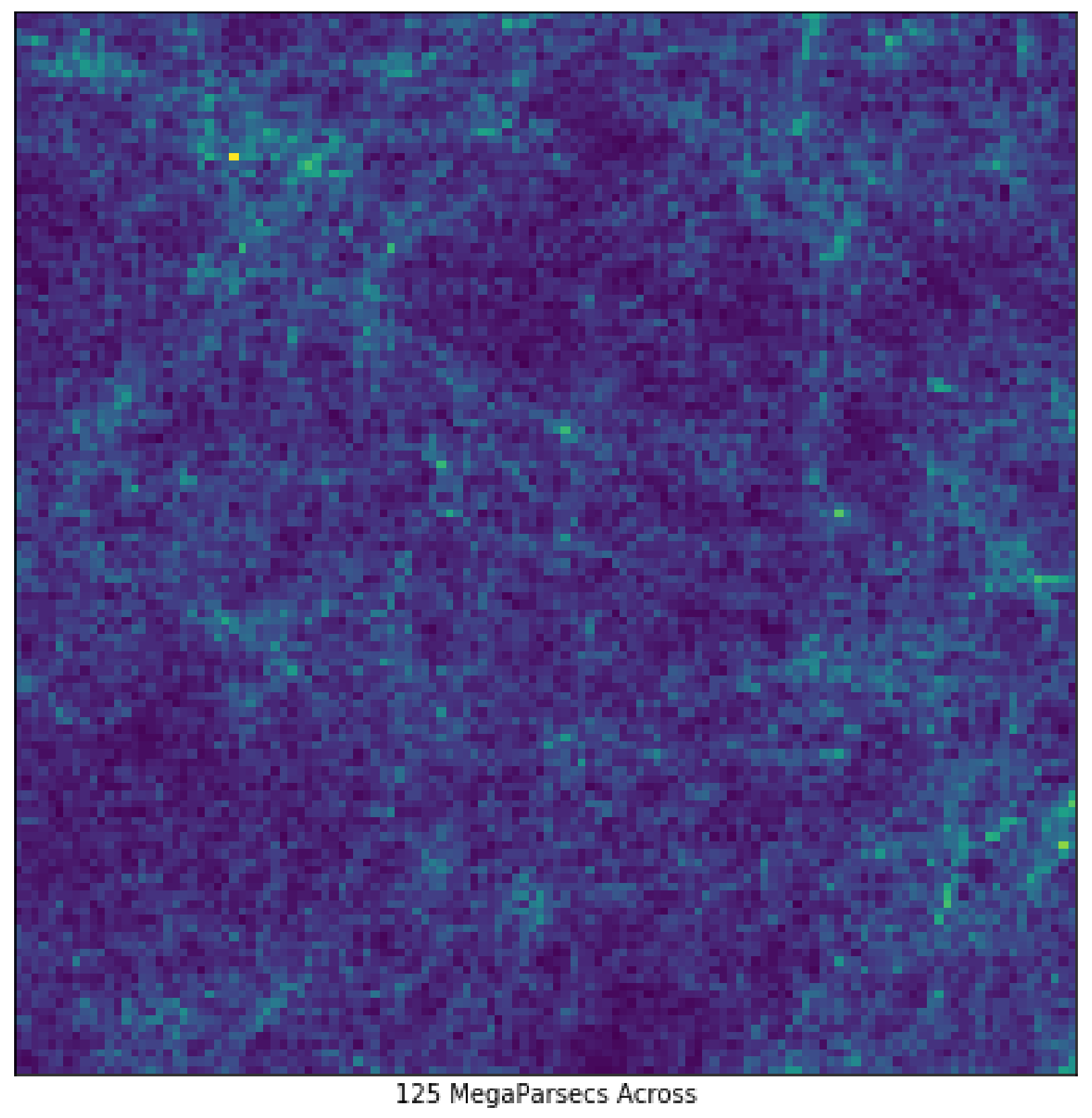
1. Construct a numerical window representative of limited visibility; for our purposes, the window is a spherical shell
2. From the Dark Sky dark halo position data: grid, Fourier transform, and compute power spectra for original data set, shelled set, and window function
3. Compare the power spectra, specifically for the equation: P(Shell) = P(Original) * P(Window)

Conclusion:

The power spectra of halos have a shape similar to that of dark matter. The implementation of a window function, as expected, has a significant impact on the power spectrum. Small values of k represent large scale cosmological structure while large values represent fine structure. The data agrees with the power law.

Halo Distribution:

A visual representation: The image depicts the distribution of dark halos over a region 125 Mpc across. For reference, one gigaparsec is about 1/14 the distance to the edge of the observable universe. Blue regions are empty and lighter regions have a denser distribution of halos. The web-like clustering pattern is clearly visible by eye.



125 MegaParsecs Across

References:

This publication makes use of data from the Dark Sky Simulations Collaboration: S. W. Skillman, M. S. Warren, M. J. Turk, R. H. Wechsler, D. E. Holz, and P. M. Sutter. Dark Sky Simulations: Early Data Release. arXiv:1407.2600, July 2014. URL http://arxiv.org/abs/1407.2600.