

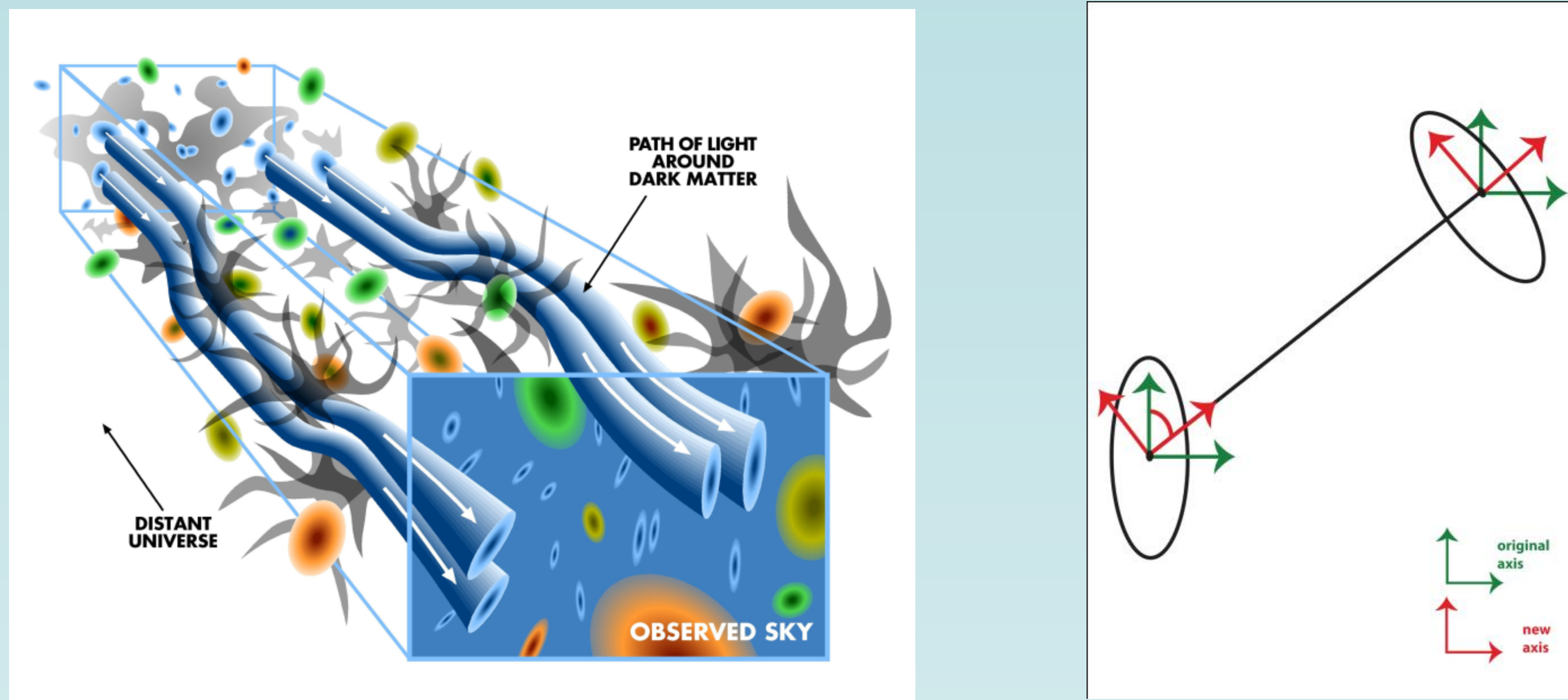
Implementation of the Shear Correlation Function and the Matter Power Spectrum in R

Allison A. Scheppelmann¹, Deborah J. Bard²

¹California Polytechnic State University, San Luis Obispo, CA ²SLAC National Accelerator Laboratory, Menlo Park, CA

Introduction

Our current knowledge about the large scale structure of the Universe can be partly attributed to the information that has been observed and calculated concerning the distribution of and shapes of galaxies. The bending of light by gravitational potential leads to an effect on how we see distant galaxies in the universe, which is known as weak gravitational lensing (see below). We can analyze this weak gravitational lensing and further understand it by calculating the shear correlation for galaxy clusters.



The Calculations

The calculation of the shear correlation begins with a dataset containing information about galaxies observed in a part of the sky. For each galaxy the given information is the right ascension, declination, and ellipticity components. Using the ascension and declination the galaxies are binned according to their distance from the starting galaxy. Then the following calculation takes place for each bin. Using the right ascension and declination the angular distance, Θ , can be calculated for each galaxy with respect to the given starting point. Once this angle is calculated, the tangential component, e_T , and cross component, e_X , for each galaxy can be calculated (see above). Once these components are calculated, the plus correlation value, ξ_+ , and the cross correlation value, ξ_X , for this pair of galaxies can be calculated. This process is repeated using each galaxy as the starting galaxy.

Once the average of the plus correlation value is calculated for each bin, the matter power spectrum can be calculated. This is done using the formula

$$P_K(\ell) = \sum_0^{\theta_{\max}} \Delta\theta \cdot \theta \cdot \xi_+(\theta) \cdot J_0(\ell\theta)$$

where $\Delta\Theta$ is the length of the bins. This formula is derived from the relationship between the shear correlation function and the matter power spectrum [1]. Calculating the experimental matter power spectrum from the shear correlation function is an uninvestigated method. Generally, the theoretical matter power spectrum is first calculated and then the shear correlation function is calculated to be used for analysis against the experiment shear correlation function.

Algorithmic Development in R

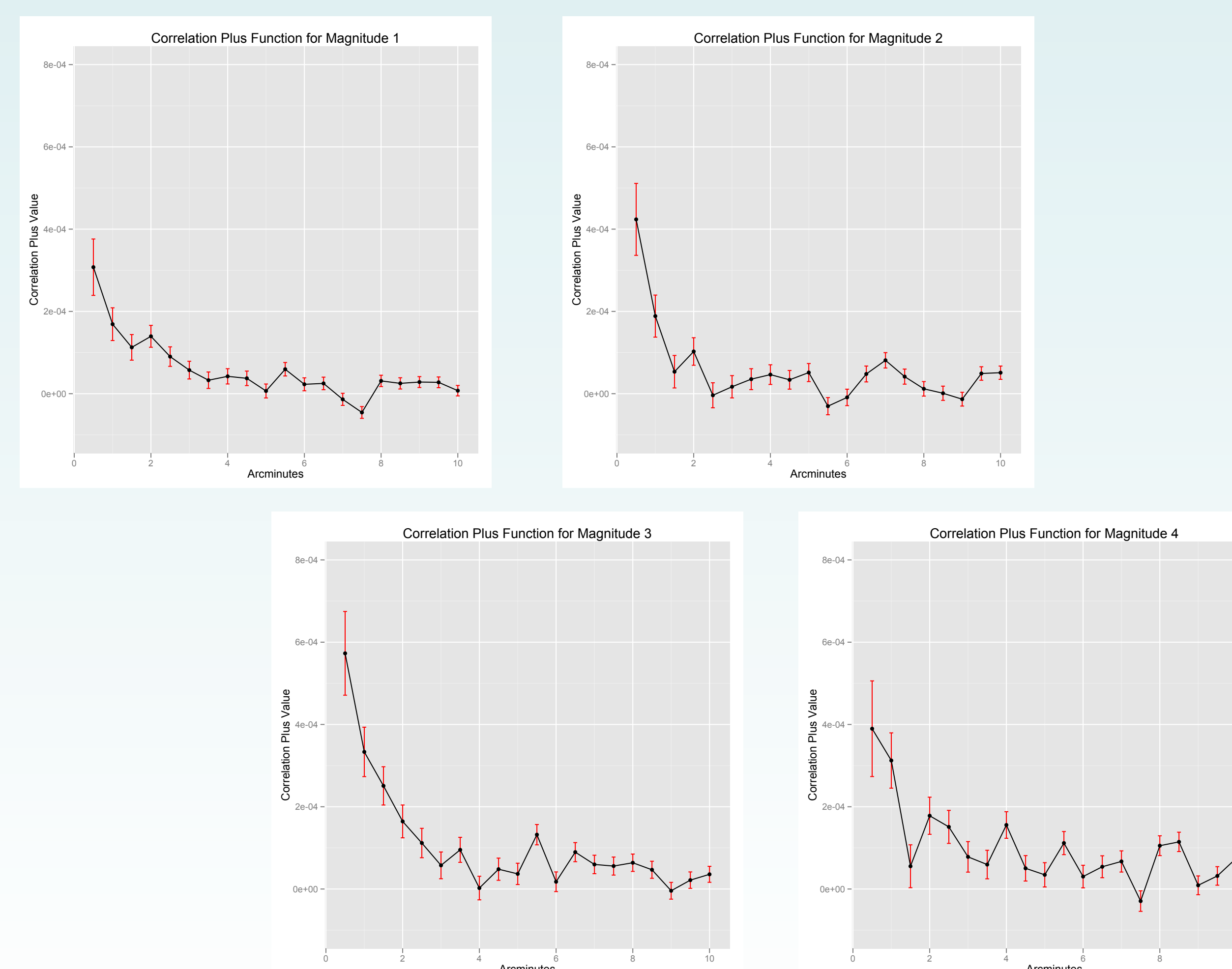
The calculation can be executed using a number of programming languages including Python, C++, Mathematica and R. However, calculations in Python, C++, and Mathematica are often strenuous and have large running times. In order to combat this problem, R was used to find the shear correlation function and the power spectrum. A further decrease in running time was accomplished by using parallelization in R. This was done by using built in packages within the R code. These packages created the option to run specific functions in parallel. The functions that were attempted in parallel are *mapply* and *adply*.

These functions were used twice in the the code. Testing was conducted in order to determine the best functions to run in parallel. The following table describes the results. As the table shows, the best results were achieved using *adply* in parallel exclusively throughout the program.

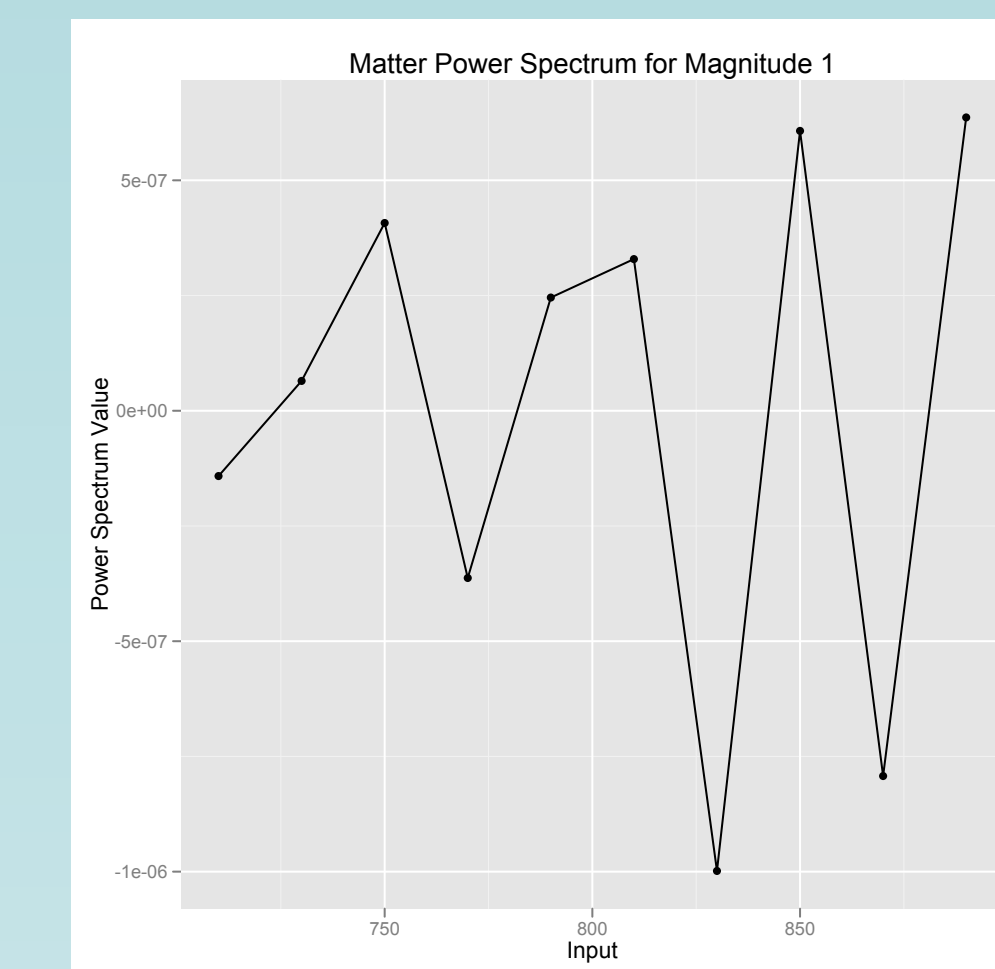
Function Used	Time to Finish Calculation (1000 Starting Points)
ADPLY, MCLAPPLY	814 seconds (13.6 minutes)
ADPLY (parallel), MCLAPPLY	1737 seconds (29.0 minutes)
ADPLY (parallel), LAPPLY	769 seconds (12.8 minutes)
ADPLY (parallel), ADPLY(parallel)	708 seconds (11.8 minutes)
ADPLY, ADPLY (parallel)	751 seconds (12.5 minutes)
ADPLY (parallel), ADPLY	860 seconds (14.3 minutes)

Computations Utilizing Algorithms in R

Upon completion of the R code, four datasets are compared. These datasets include galaxies of varying magnitude in order to determine the effect of magnitude on the shear correlation functions and matter power spectrum. The following graphs represent the shear correlation functions.



These figures show that as the galaxies grow dimmer, the correlation values increase. However, this may be an issue of redshift rather than a direct connection between the increase of the magnitude and an increase in the correlation value. This can be investigated further by obtaining the redshifts for each galaxy and then accounting for this information during the calculations.



The graph above represents the matter power spectrum. This output is currently inconclusive but some results may be available once the discrete calculation undergoes more testing and development.

Conclusion

The calculation of the shear correlation function and the matter power spectrum are intense and time consuming when programmed in certain languages. However, once these algorithms are constructed in R, the processing time decreases. The algorithms in R are also easy to read and therefore can be manipulated to the needs of the user. These developments are an aid that can be used in many projects involving weak gravitational lensing.

Acknowledgements

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Citation

[1] Bartelmann, M., Schneider P., 1999.

