

During my time at WKU, I have been involved in two major research projects. In the fall of 2009 I began my first project working with Dr. Keith Andrew on examining the ideas of nonlinearity and chaos in the context of a cosmological model formed from the coupling of Einstein's general relativity and the Klein-Gordon wave equation. With any chaotic system, an associated predictability time exists. The uncertainty in any prediction made beyond this point in the future is so large that all information of initial conditions is lost. Because the Einstein Klein-Gordon equations are badly nonlinear, it is possible that they are also chaotic, and would therefore have a predictability time. Yurov et. al. solved for a case in which these equations predicts a Big Rip, a future rapid expansion and tearing of the universe.

Because the system is nonlinear, the predictability time is extracted by linearization: reducing two second order PDEs to four first order PDEs, finding the Jacobian matrix around critical points of the system, and then taking the reciprocal of the eigenvalues. By finding the predictability time and reducing it (and the Big Rip time) to dependence on the cosmological constant, I ultimately found that the Big Rip occurred *after* the predictability time of the system, rendering the Big Rip prediction doubtful.

This work was done using *Mathematica* for analysis. This was developed into my honors capstone thesis, for which I received a "pass with distinction". I am currently in the process of publishing my work to the arXiv, an online archive of research papers in quantitative sciences.

In the summer of 2011, I began work with Dr. Ivan Novikov in theoretical nuclear physics. He was calculating the radii of different nuclei by simulating nuclei collisions using the Glauber theory framework. These calculations required us to perform Monte Carlo integration in order to find the reaction cross section of the nuclei. By adjusting the parameters of the nucleon distribution, the radii of the simulated nuclei could be adjusted, and the resulting calculated cross section could be matched to experimental data.

Monte Carlo integration is a method of numerical integration that utilizes random numbers, which must first be generated by one of many random number generators; in our case, the Metropolis-Hastings random walk algorithm. The parameters of this algorithm can be adjusted so that it produces higher or lower quality sets of random numbers as determined by the lag-1 autocorrelation of the set of numbers. I studied how step distribution standard deviation parameter could be varied so as to produce the highest quality random numbers, and how this quality effected the cross section calculation. I found that higher autocorrelation in the sets of numbers result in larger error in the Monte Carlo integration for which they are used.

I have also investigated the similarities between lag-1 autocorrelation and the power-law turnover point of the power spectrum of the random numbers, a diagnostic used by certain physics communities. cursory research indicates that they are optimized at the same parameter, and further work will be investigating whether these two diagnostics are truly measuring the same property of the random number set. This research was performed by programming in C, and in parallel using the MPI library. This work will be published as part of a future paper on the subject of Glauber theory cross-section calculations.