Charged Particles in Chaotic Magnetic Fields

Carolina L. Vega Recalde[1] (carollv@okstate.edu), J. Heerikhuisen[2], B. Dasgupta[2]
[1]College of Engineering, Architecture, and Technology, Oklahoma State University, Stillwater, OK 74074, United States
[2]University of Alabama in Huntsville, Huntsville, AL 35899, United States

Abstract

As new questions arise as of how particles travel through space, new methods of answering these questions can be implemented. By using chaotic streamlines in the Arnold-Beltrami-Childress (ABC) flows, particles can be set in motion at any point on an imaginary 2π cube. Trough computer codes written to track the different paths these particles can take, the paths can be observed.

A chaotic magnetic field is recreated and introduced through a computer code as well as the magnetic field that has a determined start and end position.

The purpose of this experiment is to observe the charged particles on the chaotic magnetic field and on the constant magnetic field. Through tracking the distances the particle traveled to go during an allocated time the diffusion of particles in magnetic fields can be further understood, however, not completely.

Introduction

The ABC flows equation was modified for this project – added is the constant magnetic field;

$$B_x = \alpha\,[A \sin(z) + C \cos(y)]$$
$$B_y = \alpha\,[B \sin(x) + A \cos(z)]$$
$$B_z = \alpha\,[C \sin(y) + B \cos(x)] + 1$$

The chaotic magnetic field is controlled by different parameters – A, B, and C. As one of the parameters goes to zero, in this case C, the chaos is decreased. Alpha (α) is the parameter that controls what percent of This field is introduced into the constant magnetic field.

X, Y, and Y were given initial conditions that depen-ded on the number of points traced. And thro-ugh the Runge-Kutta meth od the magnitude of Bx, By, and Bz were computed. This method was chosen because of its accuracy.

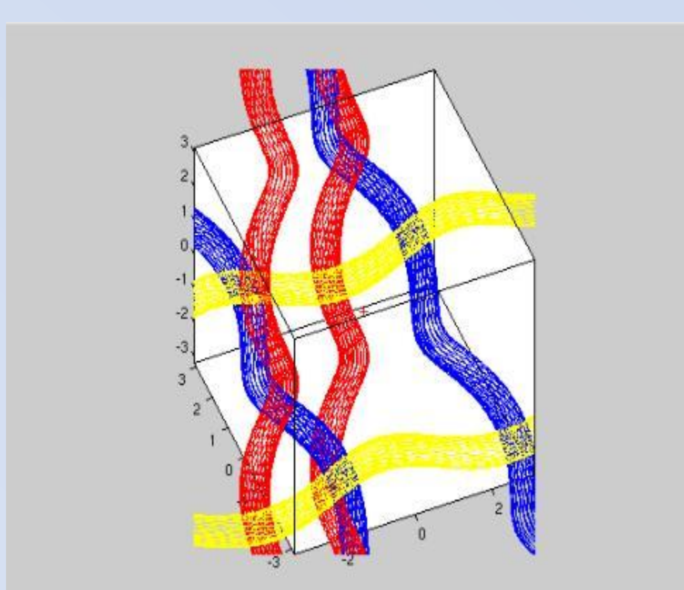
Figure 1. Six principal vortexes

Poincare sections of the cases of the magnetic fields were produced.

The purpose of the Poincare sections is to provide detailed visualization of the Lagrangian structure of the ABC flows by numerical techniques. The Poincare sections are used for detailed studies of the dynamical system defined by the trajectories of the particles; the flows exhibit a mixture of ordered regions and chaotic regions.

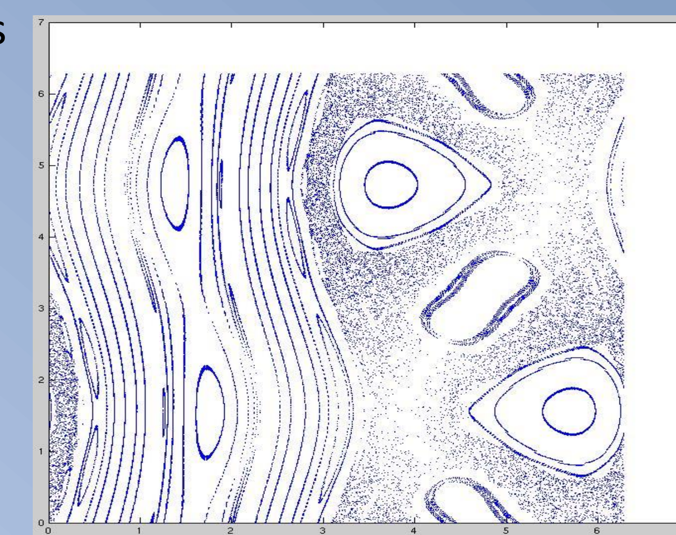
Figure 2. Poincare Section of Vortexes

Procedure

The parameters were set to $A^2 = 1$, $B^2 = 2/3$, and $\alpha = 0.5$. C varied between 0.1 to 0.8. Once inputted, the code was run on the cluster and the distance the particles (24^3) took to travel for a set time (1000 time units) were obtained. Histograms (Frequency vs. Distance) were made to show these distances. Also, the respective Poincare sections were made to illustrate the chaos produced by these parameters.

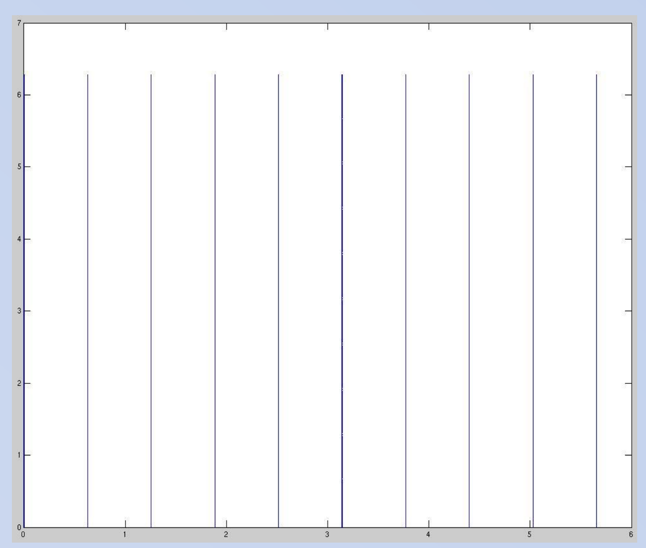
Figure 3. Poincare Section C=0.0

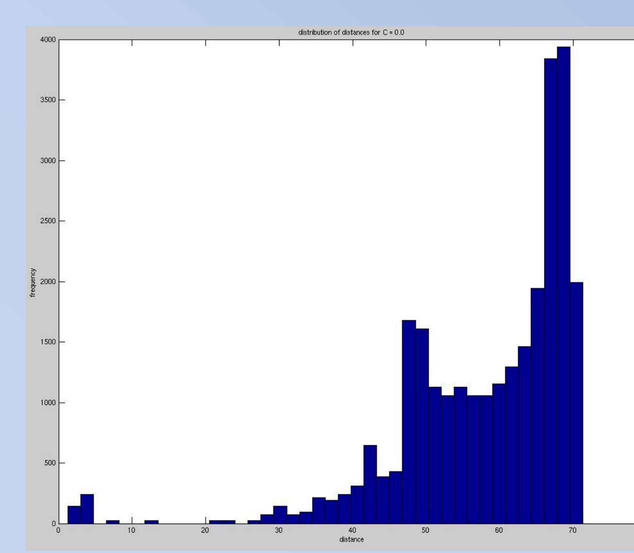
Figure 4. Frequency vs Distance C=0.0

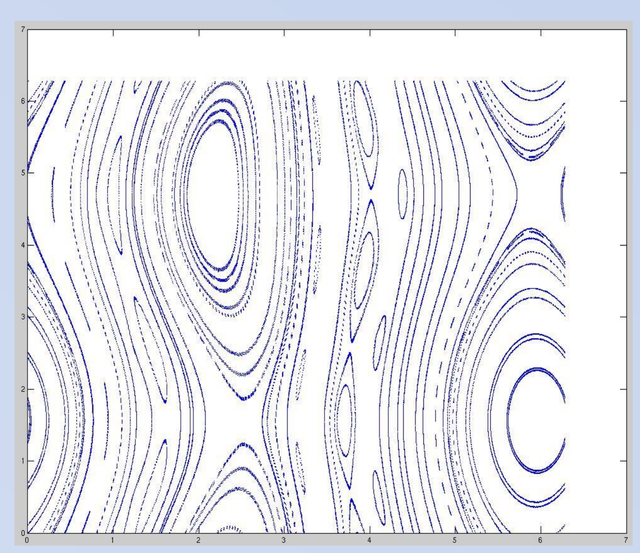
Figure 5. Poincare Section C=0.2

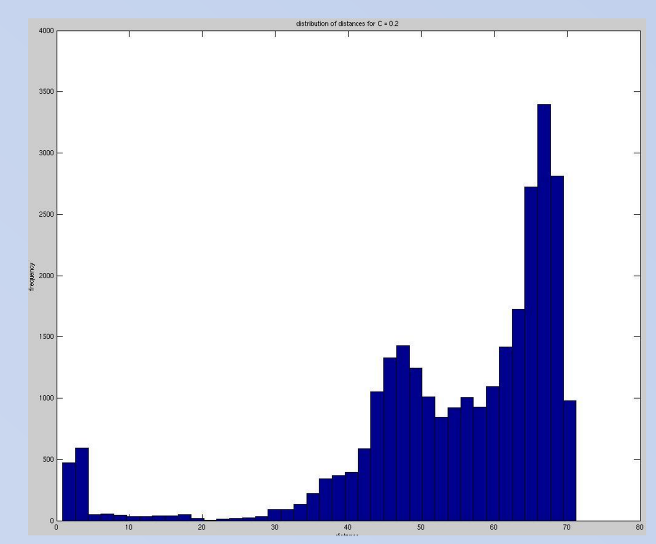
Figure 6. Frequency vs. Distance C=0.2

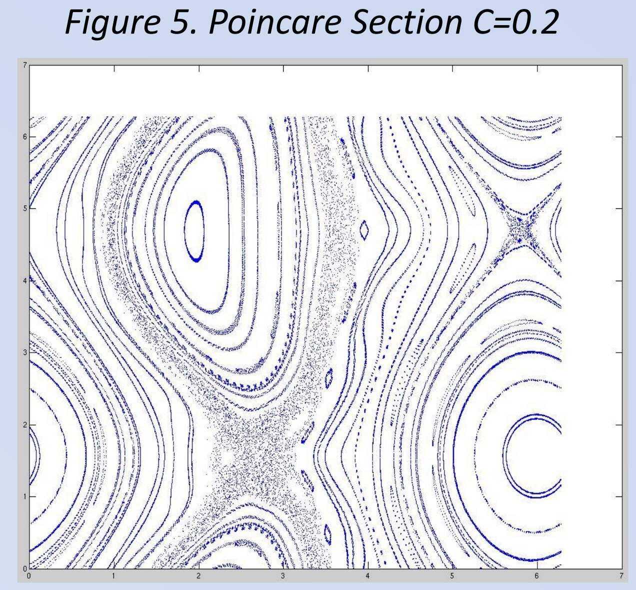
Figure 7. Poincare Section C=0.4

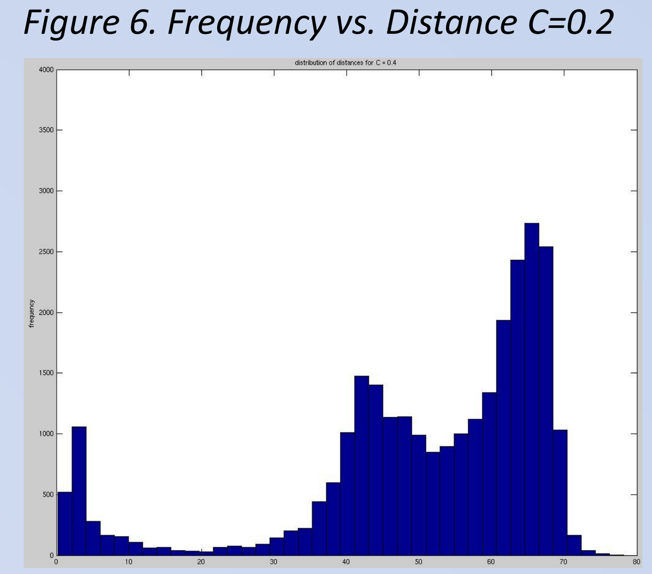
Figure 8. Frequency vs. Distance C=0.4

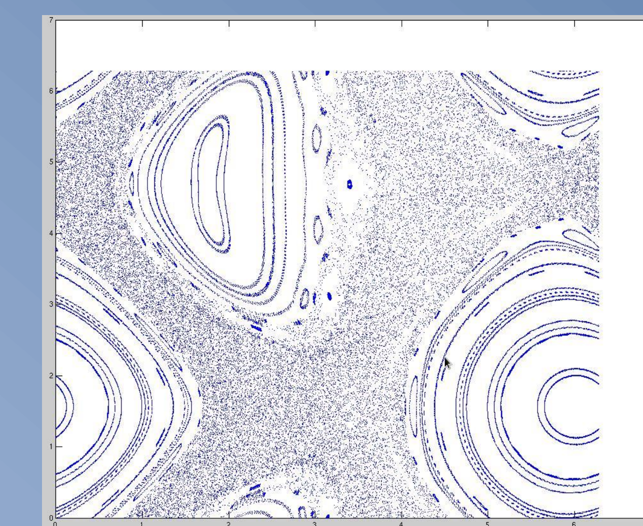
Figure 9. Poincare Section C=0.6

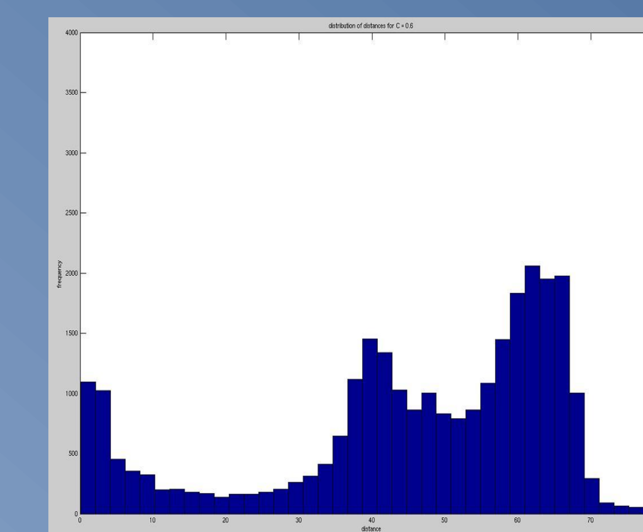
Figure 10. Frequency vs. Distance C=0.6

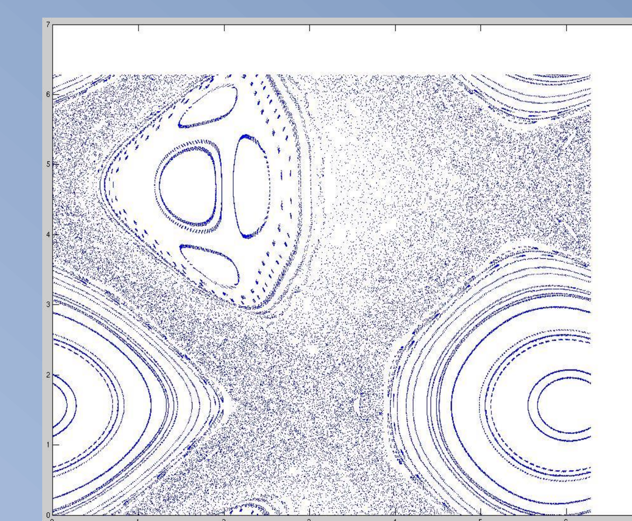
Figure 11. Poincare Section C=0.8

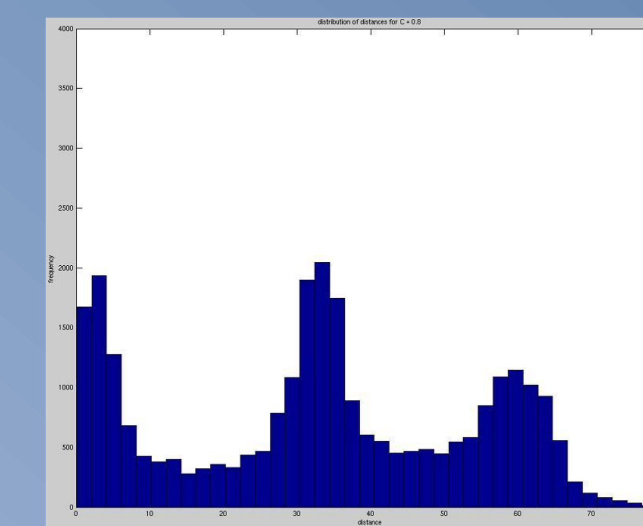
Figure 12. Frequency vs. Distance C=0.8

Conclusion

The results gave way to very interesting observations. The amount of chaos on a magnetic field can be correlated to the distances a particle travels once it is released on the field. The Poincare sections show that this field can be similar to that found in Solar Wind turbulence. How Solar Wind turbulence works has many unanswered questions, since the equation used to recreate the B field, is defined everywhere additional studies can be conducted to further understand how particles behave on these conditions.

References

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