PROJECT SUMMARY

Collaborative Research: Nonlinear magnetohydrodynamic and kinetic processes: theory, SSX experiments, and connections to space and astrophysics

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Nonlinear Magnetohydrodynamics (MHD), turbulence and magnetic reconnection are fundamental processes in basic plasma physics that have been increasingly recognized as being of great importance in characterizing and understanding phenomena in space and astrophysical plasmas. A relatively small scale experimental plasma device such as the Swarthmore Spheromak Experiment (SSX) is well suited to study of basic physical processes, and is therefore ideal for making connections with basic physical processes in these cosmic plasma contexts. The present proposal is to continue collaborative and theoretical support for SSX experiments and their interpretations, and in addition to provide connections with theoretical and observational space physics and astrophysics. In recent years the activities in this project have centered around understanding the phenomenon of magnetic reconnection occurring between two spheromak configurations, and the related production of suprathermal energetic particle populations. Attention has focused on describing the three dimensional structure of the reconnection region between the spheromaks, and interpreting the results in terms of reconnection theory, including possible kinetic signatures within a few ion inertial scales of the separator or null point in the magnetic field. Here, we review prior accomplishments and ongoing work, and present a plan for further reconnection and particle acceleration studies. The proposed research includes efforts to understand the nonlinear dynamics of SSX when it is run in a new mode– the so-call FRC or Field Reversed Configuration. In this case the initially generated spheromaks are less constrained than they were in the reconnection configuration, because the slotted conducting plates between them have been removed. Reconnection can, and still does occur. But now the spheromaks can fully merge, tilt, and seek a new lower energy equilibrium state. The FRC configuration allows us to explore the close connections between reconnection and turbulence in detail. Reconnection phenomena include current filamentation, magnetic topology change, plasma jetting and energization of particles by MHD electric fields. Reconnection is usually studied in configurations in which the large scale magnetic field geometry is supported by boundary conditions (e.g., applied electric field or externally supported currents). However reconnection is also a characteristic feature in homogeneous MHD turbulence, where it may occur at many sites, between merging magnetic islands or plasmoids. Consequently there is a profound connection between large scale reconnection and MHD scale turbulence, and this fundamental nonlinear process is expected to give rise to distinctive signatures in both laboratory and astrophysical plasmas. In the coming grant period we will will broaden our theoretical and modeling efforts to understand the nonlinearity, turbulence and particle energization that occurs in FRC dynamics. This will include new three dimensional simulations of both SSX and homogeneous turbulence, associated test particle calculations, and theoretical modeling. Observational and theoretical connections will be made to astrophysical energetic particles, reconnection in the magnetosphere, and contributions to Ohm's law in the solar wind. As has been the theme of this project in the past, we will maintain strong involvement of students, and a close coordination between the experimental data and the theoretical efforts.