DOE Grant DE-FC02-01ER54652

"Magnetic Reconnection Code: Applications to Sawtooth Oscillations, Error-Field Induced Islands, and the Dynamo Effect"

Final Report

Richard Fitzpatrick

Richard Fitzpatrick has written a time-depedent, two-dimensional, semi-implicit, second-order finite difference, compressible MHD code in order to investigate the interaction of tearing modes with flow and external magnetic perturbations. The code has been successfully benchmarked against both linear and nonlinear theory. The code was used to investigate error-field penetration in flowing plasmas. In this investigation, the error-field was ramped up very slowly, since experimental error-fields are quasi-static. In the so-called visco-resistive regime, which is relevant to modern-day tokamaks, the scaling of the numerical penetration threshold was found to agree very well with a previous analytic theory of Fitzpatrick. A paper reporting this investigation was published in Physics of Plasmas.

The same code was used to investigate the so-called Taylor problem, in which a tearing stable plasma is subject to a suddenly imposed external magnetic perturbation. The results of this investigation have been used to verify previous analytic theory, and to show that recent criticisms of this theory are unfounded. A paper reporting this investigation was published in Physics of Plasmas.

Richard Fitzpatrick employed the University of Chicago's FLASH code in order to further investigate the Taylor problem. Using this code, a new aspect of the problem was discovered. Shortly after the application of the external perturbation the plasma response is not well-described by conventional asymptotic matching theory. An alternate deccription has been developed in which compressible Alfvèn waves traverse the plasma, reflecting off the walls, and driving transient reconnection as they pass the resonant surface. This description has been verified numerically using the FLASH code. For very suddenly applied perturbations, the peak pulse driven reconnection rate can far exceed that predicted by conventional asymptotic matching theory. A paper reporting this investigation was published in Physics of Plasmas.

Richard Fitzpatrick has written a 2-D Hall MHD code, and used it to investigate the collisionless Taylor problem. Focusing on the scaling of the peak reconnection rate, extensive scans of parameter space have been performed. These scans have resulted in a set of novel scaling laws for the rate of forced reconnection in the Hall MHD regime. A paper reporting this investigation was published in Physics of Plasmas.

Frank Waelbroeck has performed an investigation of the scaling of the error-field penetration threshold in collisionless plasmas. A paper reporting this investigation was published in Physics of Plasmas.

Paul Watson and Richard Fitzpatrick have written a fully-implicit extended-MHD code using the PETSC framework. The code was used to investigate the physics which determines the phase-velocity of a comparatively wide, isolated, magnetic island. The phase velocity was found to be fixed by momentum transport across the magnetic flux surfaces in the region immediately surrounding the magnetic separatrix. Analytic predictions for the phase velocity were obtained, and were successfully benchmarked against the code.q A paper reporting this investigation was published in Physics of Plasmas.