

Abstract

The problem of plasma turbulence and dynamics, and their effects on charged particles, is fundamental in space, astrophysical and laboratory plasma physics, in cosmic ray modulation, solar energetic particle transport, shock acceleration, wave particle interactions, and energy confinement in plasma experiments.

In this thesis statistics of test particle transport are obtained by computation of test particle trajectories in model turbulence, represented by superimposed static slab magnetic fluctuations, 2D magnetic fluctuations and a uniform background magnetic field [Mace et al, 2000, ApJ, 538:192]. For different parameter regimes, we calculate statistics corresponding to perpendicular and parallel transport for time scales Vt/λ (where V is particle speed, t is time, λ is correlation scale) up to several hundred. Parallel and perpendicular diffusion coefficients are computed simultaneously in several different ways and compared with theoretical results, including quasilinear and nonperturbative scattering theories. Subdiffusive transport, which agrees well with theory of Kota and Jokipii, 2000, ApJ., 531:1067, is observed in nearly pure slab model turbulence magnetic field. True compound diffusive transport, which has not any theoretical explanation currently, is seen in composite ($E^{slab} : E^{2D} = 20 : 80$) model. Velocity space diffusion coefficients in weak turbulence are computed directly from test particle trajectories and compared with quasilinear theory and it can be shown that some of the discrepancy between the simulations and quasilinear theory can be explained by trapping width theory [Karimabadi et al, 1992, JGR, 97:13853].

Results from a three-dimensional (3D) axisymmetric resistive magnetohydrodynamic (MHD) simulation are compared to experimental data from the Swarthmore Spheromak Experiment (SSX) [Brown, 1999, Phys. Plasmas, 6:1717]. The MHD simulation is run under conditions and with dimensionless parameters similar to the experiment (Lundquist number $S = 1000$, plasma beta $\beta = 0.1$). The simulation is shown to reproduce global equilibrium magnetic field profiles of the spheromaks as well as much of the detailed reconnection dynamics measured when two spheromaks are merged. It is concluded that SSX merger dynamics may be characterized as MHD reconnection, with the likelihood that extensions are needed to account for kinetic effects in the associated current sheet. Test

particle simulation is also run with dimensionless parameters similar to the SSX using high spatial and temporal resolution MHD simulation data as input for a particle orbit and energization code, and particles are permitted to escape when they encounter the simulated SSX boundaries. The MHD activity related to reconnection is responsible for accelerating charged particles.