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Enhanced Superbanana Transport Caused by Chaotic Scattering across an Asymmetric Separatrix[1]

DANIEL DUBIN[2], Univ. of California, San Diego

This talk discusses a novel "chaotic" form of superbanana transport, and compares theory to experiments on nonneutral plasmas.[3] Magnetically-confined plasmas often have one or more locally-trapped particle populations, partitioned by separatrices from one another and from passing particles. Strong superbanana transport is caused by particles that cross these separatrices in the presence of field "errors" (such as toroidal magnetic curvature), since trapped and passing particles respond to the field error differently.[4] Collisional scattering (at rate ν) is one mechanism driving the separatrix crossings; theory predicts a collisional boundary layer at the separatrix energy, and collisional transport that scales as $\nu^{1/2}B^{-1/2}$. The chaotic transport of interest here occurs when the separatrix is "ruffled" in the direction of plasma drift; then, collisionless particle orbits (tp orbits) cross the separatrix, giving essentially random trapping and de-trapping, with transport scaling as $\nu^0 B^{-1}$. Prior theory assumed a symmetry such that these tp orbits become trapped and detrapped on the same flux surface, thereby giving zero chaotic transport and reduced collisional transport.[3] Here, we characterize chaotic transport without the assumed symmetry, and find quantitative agreement with pure electron plasma experiments and simulations in cylindrical geometry. A global field error consisting of a small tilt of the trap magnetic field is applied, to play the role of large-scale curvature in tokamaks or stellarators. Also, a separatrix with two trapped particle populations is produced by applying a "squeeze potential" to the middle section of the plasma column. When the separatrix is θ-symmetric, radial transport is observed to scale as $1/\sqrt{B}$ in agreement with standard $\sqrt{\nu}$ superbanana theory. When the separatrix is not θ symmetric, some particles transit chaotically from trapped to passing and back as they ExB drift in θ (the tp orbits). Typical field errors then cause tp orbits to trap and detrap on different flux surfaces, and enhanced transport scaling as $1/B$ is observed in the experiments, in quantitative agreement with our theory and simulations.

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[2]In collaboration with Y. Tsidulko, A.A. Kabantsev and C.F. Driscoll.

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