Particle dynamics in periodically driven systems: Fermi Accelerators and Paul Traps

Abstract:

Periodically driven systems are of immense interest in plasma physics both from the point of view of plasma confinement as well as plasma heating.

One of the models to explain plasma heating in capacitive RF discharges is Fermi acceleration, which consists of a particle moving in a dynamical billiard with oscillating boundaries. It is well known that the energy growth rate of an ensemble of particles in a strongly chaotic billiard with moving walls is quadratic-in-time whereas it can be exponential-in-time in billiards with multiple ergodic components. Since a real plasma device allows for an exchange of particles with the surroundings, we have now studied Fermi accelerators with a hole (small enough so as not to disturb the statistics). We find that energy gain is significantly higher in a leaky Fermi accelerators with multiple ergodic components and it can be further increased by shrinking the hole size. In the ergodic case, energy gain is found to be independent of the hole size. Work done jointly with V. Gelfreich, V. Rom-Kedar and D. Turaev [Physical Review E 91, 062920 (2015)].

Paul trap is a device used to confine electrons by using time-periodic spatially non-uniform electric fields and a Nobel Prize as awarded for its discovery in 1989. The time-averaged distribution function of plasma in such devices is usually modelled using the concept of an effective potential (ponderomotive theory). For a specific example of the electric field used in Paul traps, we had shown earlier that the exact solutions of the Vlasov equation (collisionless Boltzmann equation) do not agree with solutions obtained by the effective potential approach. Now we have been able to obtain a perturbative solution of the Vlasov equation for a much more general case and find the same discrepancy with conventional theory. These perturbative solutions represent a non-equilibrium steady state and further work needs to be done to understand their statistical evolution. Work done jointly with A. Srinivasan [arXiv:1510.03974].