Low-dimensional chaos in the self-consistent wave-particle interaction

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Abstract

We analyze nonlinear aspects of the wave-particle interaction using Hamiltonian dynamics and considering a low-dimension realization of the single wave model. Wave-particle interaction plays an important role in plasma dynamics, notably in plasma instabilities and turbulence. This interaction generates regular and chaotic trajectories of particles in (x, v) space. Regular trajectories may lead to coherent particle acceleration while chaotic ones are responsible for particle heating and escape.
To focus on elementary aspects of the dynamics, we start with the simple case where one particle (N = 1) is coupled to one wave (M = 1) in one space dimension [1]. This case is completely integrable, so that the wave potential pulsates while the particle is either trapped or circulating ; orbits are periodic (in a proper frame), and the bifurcation diagram of this simple system is already rich, with a saddle-centre coalescence and a special role of the trajectory for which the wave intensity goes through zero at a single instant.

On increasing the number of particles (N = 2, M = 1), chaos arises due to the strong sensitivity on the initial condition of relative velocity or relative position of the particles. Continuous time behaviours are also analyzed through particle motion in the energy and wave comoving frame.

1. J.C. Adam, G. Laval and I. Mendonça, Phys. Fluids 24, 260-267 (1981).

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